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MINERALS

AND

HOW THEY OCCUR

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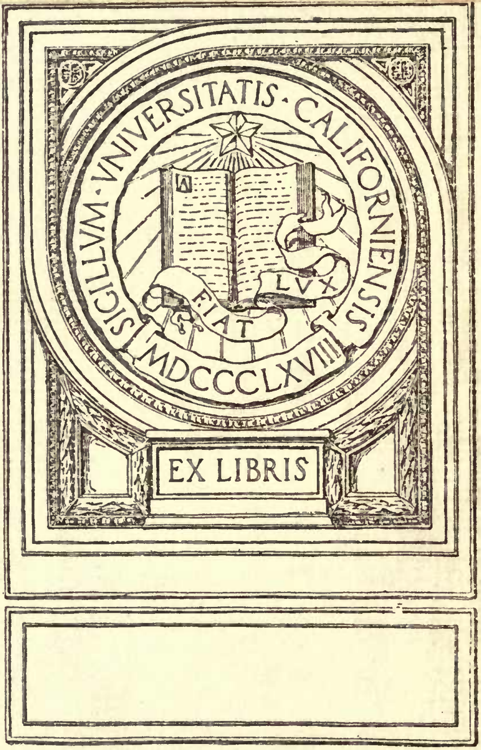

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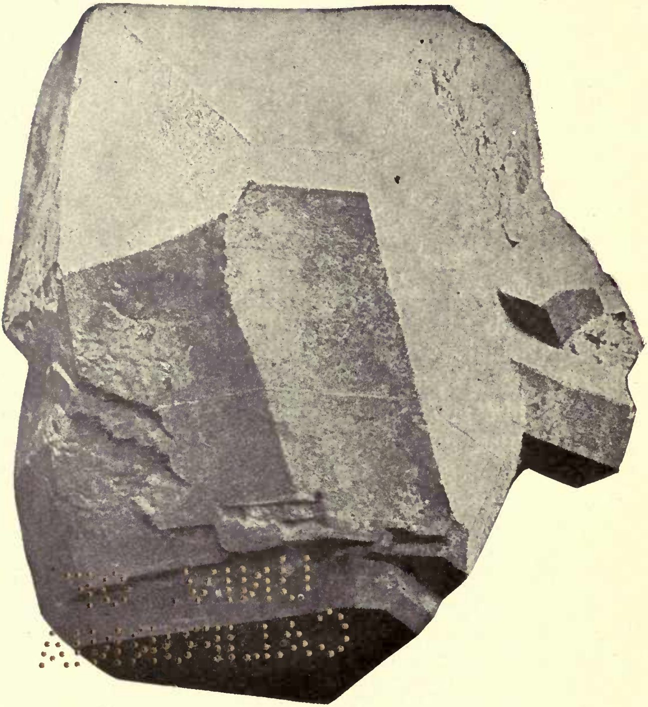

FIG. 1. *Frontispiece.*

Crystal of Feldspar (orthoclase), natural size, with two smaller crystals of the same mineral attached. From a photograph of a specimen from Bird's Creek P.O., Hastings County, Ont., in the collection of Prof. Wm. Nicol.

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MINERALS

AND

HOW THEY OCCUR

A BOOK FOR SECONDARY SCHOOLS AND PROSPECTORS

BY

WILLET G. MILLER

Provincial Geologist of Ontario; formerly Professor of Geology in the School of Mining, Queen's University, Kingston, Canada.

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PREFACE

In this little book an attempt has been made to give the chief characteristics of the more commonly occurring and more useful minerals. In order that the minerals should not be studied as mere specimens, an outline of their modes of occurrence and origin has been added. The book deals, therefore, with both mineralogy and geology. Since, however, only slight reference has been made to certain geological phenomena, it has been thought better to restrict the title to mineralogy.

It is hoped that the book will, in some measure at least, meet the needs of the general reader and the prospector for minerals, as well as those of the student in the secondary schools. We have tried to make the study, as far as possible, an outdoor one, and to draw the reader's attention to minerals and rocks which he can obtain in most neighborhoods, and to descriptions of phenomena which he can verify for himself. Owing to the fact that volcanic action, mountain structure, or even exposures of compact rock in place, and other phenomena on which much stress is laid in many elementary books, cannot all be studied in most populated districts, the references to some of them are brief. We have also sought to explain in a practical way such terms as are commonly met with in the daily press or in ordinary periodical literature, with which every person professing to have a liberal education should be acquainted.

In order to keep within the space allotted to us, the description of historical geology is brief. The age names which are commonly used are, however, explained. It

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appears to the author that the numerous descriptions of fossils which are given in many elementary text-books simply tend to burden the memories of readers, if indeed they attempt to learn them, and can well be left to more advanced treatises. If the study of science is not made practical, the learner can employ his time to more advantage in reading history and romance or in the study of languages.

It is assumed that most of our readers will have some knowledge of physics and chemistry which form the groundwork for a thorough understanding of mineralogy. An acquaintance with the latter is essential to the geologist. He must have a knowledge of mineralogy before he can properly understand the character of rocks and the effects which are produced on them by atmospheric and other agencies.

Since most common minerals can be identified without the use of chemical or blowpipe tests, the description of these tests has been placed in an appendix. This will avoid confusing the reader who may have little chemical knowledge or who will not always have the requisite reagents and apparatus at hand.

Numerous excellent books are available for the reader who wishes to supplement the descriptions on the following pages. A small list of such works will be found at the end of this volume.

The author is indebted to several of his friends for criticisms on the text and for the use of photographs.

To Professors Goodwin, Nicol, Brock, and Mr. M. B. Baker, of the Kingston School of Mining, special thanks are due for the interest they have taken in the preparation of the book. I am much indebted to members of the staff of the Geological Survey of Canada, whose names are given in connection with the illustrations, for the use of photographs.

Professor N. R. Carmichael, of Kingston, has kindly furnished me with a number of photographs. Figs. 3, 4, 7, 14, 32, 35, 36, 39, 41, 42, 46, 53, 55, 62, 65, 66, 70, 71 *bis*, 104, 107, 108, 109, are reproduced from these.

Use has been made of a number of the wood-cuts which were employed in illustrating the works of the late Professor Chapman, and which are now in the possession of the publishers of this book.

Since it is likely that some, at least, of our readers will desire to obtain specimens of minerals, rocks and fossils, which they are unable to collect for themselves, I am permitted by the Professor of Mineralogy of the School of Mining, Kingston, Ont., to say that he will furnish price lists on request. Lantern slides of many of the illustrations in this book can be ordered through Professor Carmichael.

W. G. M.

Toronto, April, 1906.

CONTENTS

PAGE

Frontispiece—"Feldspar Crystal."

PREFACE

PART I

INTRODUCTION 1

ROCKS AND MINERALS 2

SAND AND CLAY 8

CONGLOMERATE AND BRECCIA 12

MARKINGS ON ROCKS 14

FOSSILS AND LIMESTONE 17

CLASSES OF ROCKS 21

ACTION OF WATER AND OTHER AGENTS 23

Animals and Plants 32

Volcanoes and Earthquakes 32

PART II

A.—PHYSICAL CHARACTERS OF MINERALS 36

Systems of Crystallization—Cleavage—Hardness—Magnetism —Lustre or Aspect—Color—Streak—Fusibility—Transparency—Taste and Odor—Specific Gravity.

USE OF PHYSICAL CHARACTERS 49

TABLE FOR DETERMINATION OF MINERALS 50

B.—DESCRIPTION OF MINERALS 54

I—*Native Elements:* Graphite and other forms of Carbon—Sulphur—Gold—Silver—Platinum—Copper—Iron 55

II—*Sulphides and Arsenides:* Iron pyrites—Marcasite—Pyrrhotite—Copper pyrites—Bornite—Arsenical pyrites or Mispickel—Niccolite—Smaltite—Galena—Zinc Blende or Sphalerite—Stibnite—Chalcocite—Argentite—Cinnabar—Bismuthinite 64

III—*Chlorides and Fluorides:* Rock Salt—Fluor Spar 73

PAGE

IV—*Simple Oxides:* Quartz and varieties—Hematite—Magnetite—Limonite—Corundum—Cassiterite—Pyrolusite .. 75

V—*Carbonates:* Calcite—Aragonite—Dolomite—Siderite—Malachite—Azurite 84

VI—*Silicates:* Mica—Feldspar—Amphibole—Pyroxene—Olivine—Garnet—Tourmaline—Topaz—Serpentine—Talc—Chlorite—Kaolinite—Epidote—Zircon—Scapolite—Beryl—Nepheline—Sodalite 88

VII—*Sulphates:* Gypsum—Anhydrite—Celestite—Barite 104

VIII—*Phosphates:* Apatite 108

REVIEW NOTES—List of Common Minerals—Scale of Hardness—Specific Gravity—Crystals—Localities............... 110

PART III

ROCKS AND ROCK STRUCTURES 113

Classification of Rocks 113

A.—IGNEOUS ROCKS 114–118

Volcanic and Plutonic Rocks defined—Dikes and Veins—Names of Igneous Rocks—Table of Igneous Rocks.

Representative Plutonic Rocks 120

Granite—Syenite—Diorite—Gabbro—Norite—Anorthosite.

Representative Volcanic Rocks.......................... 124

Obsidian—Rhyolite—Pumice—Pitchstone—Felsite—Trachyte—Andesite—Basalt—Diabase—Trap—Porphyry.

B.—AQUEOUS ROCKS.......................... 128

1. Arenaceous Rocks 131

Sand—Sandstone—Conglomerates—Arkose.

2. Argillaceous Rocks 132

Clay—Shale—Slate.

3. Calcareous Rocks.......................... 135

Limestone—Marl—Chalk.

Rocks of Organic Origin.......................... 139

Limestone—Coal Beds—Infusorial Earth or Tripolite—Phosphatic Deposits—Iron Ores.

Chemically-formed Rocks 140

Common Salt Deposits—Gypsum—Silicious Sinter.

PAGE
C.—METAMORPHIC ROCKS 141
ROCK STRUCTURES 141–149
Igneous Structures 141
Dikes—Sheet or Sill—Laccolite—Lava Flow—Columnar Structure—Amygdaloidal Texture—Volcanic Neck—Boss—Batholite.
Structures in Aqueous Rocks 143–147
Stratification—Anticline and Syncline—Current Bedding—Faults—Normal Fault—Reverse Fault—Dip and Strike—Joints.
AGE OF ROCKS 150–152
Unconformity—Use made of Fossils—Geological Scale.
AGE DIVISIONS 152–164
Pre-Cambrian 152–155
Keweenawan — Huronian — Laurentian — Keewatin — Economic Importance of Pre-Cambrian.
Cambrian and Post-Cambrian Time 156
Table showing Age Divisions 157
Systems and Formations 159
Geological Map 161
Life 162
Silurian and Devonian 163

PART IV

ECONOMIC NOTES:—

CLASSIFICATION OF ECONOMIC MINERALS AND ROCKS—

1. Metals and their Ores 167
Ore Deposits 171
Vein Stones 173
Value of Deposits 174
Terms used in Mining 175
2. Abrasive Materials 179
3. Refractory " 180
4. Paint " 183
5. Decorative " 183
6. Chemical Manufacture 184
7. Mineral Fertilizers 184
8. Fuels and Illuminating Materials 187
9. Bricks, Pottery and Glass 189
10. Stone and Cement 190
11. Waters 191
12. Miscellaneous Economic Minerals 193

PAGE

APPENDIX I

CHEMICAL AND BLOWPIPE TESTS 194-207
The Mouth Blowpipe—Fuel and Flames—Forceps—Platinum Wire—Glass Tubes—Charcoal, File and Magnet—Magnifying Glass—Chemical Reagents—Dissolving in Acids—Fusibility—Flame Coloration—Use of Cobalt Solution—Experiments on Charcoal—Roasting on Charcoal—Detection of Sulphur in Sulphides and Sulphates—Fusion with Borax and Salt of Phosphorus—Borax Beads—Sodium Carbonate—Experiments with Borax Beads—Detection of Silica—Water Test.

APPENDIX II

TABLE OF THE ELEMENTS 208-210
Elements—Symbols—Atomic Weight—Chemical Formula—Molecules—Percentage Composition—Chemical Equation.

APPENDIX III

ILLUSTRATIONS OF PRE-CARBONIFEROUS FOSSILS 211
1. FOSSIL PLANTS—
(*a*) Algæ or Fucoids—(*b*) Equisetaceæ—(*c*) Lepidodendraceæ 211-213
2. ANIMAL REMAINS—
A. Invertebrates—(*a*) Graptolites—(*b*) Corals—(*c*) Crinoids—(*d*) Star fish and related forms—(*e*) Trilobites—(*f*) Mollusca [1. Brachiopods; 2. Mollusca vera: (A) Lamellibranchs; (B) Gasteropods; (C) Cephalopods] 213-226
B. Vertebrates 226

APPENDIX IV

PRICES OF MINERALS, ORES AND METALS 227-228

APPENDIX V

LIST OF BOOKS ON MINERALOGY AND GEOLOGY 229-230

INDEX 231-252

MINERALS AND HOW THEY OCCUR

PART I

INTRODUCTION

On the following pages is given a brief account of the planet earth. The composition of the crust, or that part of the earth which is accessible to man, is described. The agencies by means of which changes are produced and the products of such agencies in the past are illustrated. Reference is made to uses by man of certain substances found in the crust.

From the foregoing it is seen that this little volume treats of the science of the earth, or what is known as Geology. Since, however, a fuller account is given of minerals, or the naturally occurring elements and compounds, than of other features of geology, it has been thought best to restrict the title to Mineralogy.

From the descriptions and the directions given on following pages the reader will learn more clearly what is meant by mineralogy and geology than he can from mere definitions. He will also learn the relationship which each of these sciences has to other sciences, such as physics, chemistry, botany, and zoology.

ROCKS AND MINERALS.

Granite is a rock some of whose characteristics and uses are as widely known as are those of most naturally occurring substances. Boulders of it are found strewn over nearly all agricultural districts in northern countries, and in rocky and barren regions it frequently occurs in large masses (Figs. 2, 84).

On account of the widespread occurrence of this rock, and from the fact that monuments and other structures made of it are to be seen in almost every district occupied by civilized people, it serves as a suitable material for the use of the beginner in the practical study of mineralogy and geology.

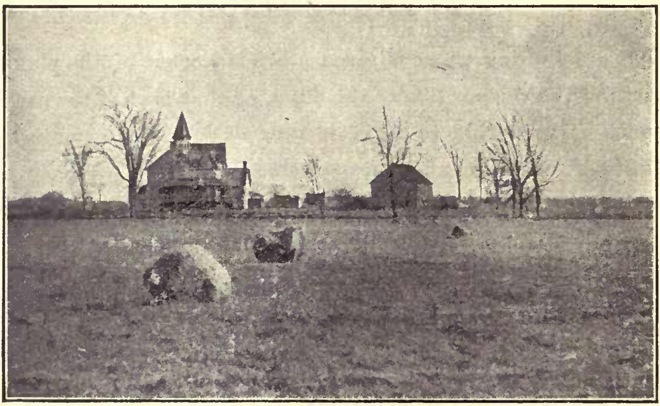

FIG. 2.
Boulders in a field near Ottawa, Ont.
[Dr. H. M. AMI, G.S.C.]

If a hand specimen of a rather coarse-grained variety of this rock, or a surface of a boulder, be examined with the unaided eye, it will be seen to be made up, usually, of grains of three substances. One of these is a hard, light-colored, glassy material which breaks with a rough or uneven fracture, and is known as *quartz*. A second, which is variable in color, but frequently pink, appears on superficial examination to be somewhat similar in character, but breaks or cleaves with smooth surfaces. It is named *feldspar*. A third substance which is present in many varieties of granite may be either black or white in color. It splits readily into thin flakes or scales, and

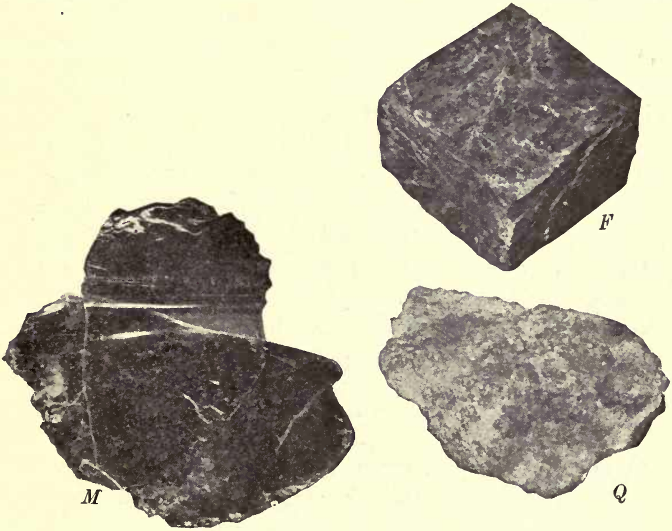

FIG. 3.

F, Cleavage piece of Feldspar ; Q, Quartz showing irregular fracture ; M, dark Mica.

is known as *mica*. These three substances possess, theoretically, a definite chemical composition, and are called minerals (Fig. 3).

The smooth or cleavage surfaces of the feldspar grains can best be detected by turning the specimen so that the light strikes it from different directions. Coarse-grained granite, containing preferably pink feldspar, should be studied first.

A magnifying glass, which need not cost more than twenty-five cents, will be found useful in examining the smaller grains. Determine whether a scratch can be made on one of the larger feldspar faces with the point of the blade of a pocket knife. Can the quartz be so marked? Break a piece, an inch or two in diameter, off a boulder or get a chip at a granite worker's or at a quarry. Find whether a grain of quartz, on a thin edge or corner of such a chip, will scratch a piece of ordinary window glass. Try a grain of feldspar in the same way. Get chips from a coarse-grained granite—the grains in boulders are frequently one-quarter inch or more in diameter—and see if the quartz will scratch the feldspar and *vice versa.* Pebbles of quartz, white or light gray in color, often an inch in diameter, are quite common in gravel pits and along the shores of lakes and streams. Get such a pebble. Make sure that it is quartz by trying your knife on it. Draw it across a piece of glass. Break it by a blow from a hammer on an anvil or on a large boulder. Are the surfaces of the pieces into which the pebble breaks similar to those of the grains of quartz on the face of a freshly broken specimen of granite?

Compare the general appearance of quartz with that of any common metal—iron, steel, or copper; a knife blade will do. It will be admitted that the quartz is more glass-like than metal-like in aspect. While its color is usually white or gray, it occurs, at times, in bluish grains in granite. Pebbles of quartz are sometimes reddish. Metals possess an aspect or lustre which is known as metallic; while substances such as quartz are said to have a non-metallic lustre. What is the lustre of feldspar and mica?

If one looks carefully among the boulders in almost any neighborhood he will find that some of them contain grains or pieces of feldspar half-an-inch or more in diameter. With a little care, one or two of them can be broken out free from quartz and other minerals.

In order to make sure that the specimens thus obtained are feldspar, try their hardness both with the knife and on glass. Feldspar of various colors is found, and a few minerals resemble it rather closely in general appearance. They can usually be distinguished from it by simple tests. Some of them are, for instance, much harder, and others softer. Note the character of the surfaces of your feldspar specimens. Break one specimen. Are the surfaces of the resulting fragments similar to those of the specimen broken?

If one cannot find mica in large enough flakes in boulders, so that specimens a half-inch or more in diameter can be broken out, he can obtain a specimen in a hardware store or tinshop, where the mineral is used for stove fronts. Mica is also employed as an insulator in electrical works. Split a thin sheet off a specimen with a knife blade. Is the sheet flexible?

Quartz is the only constant or essential constituent of granite. One or both micas are wanting in some varieties, but feldspar is rarely absent. In certain not uncommon kinds of the rock, other minerals are present in considerable quantities. It is thus seen that this rock, unlike a mineral, does not possess, theoretically, a definite chemical composition. It is a mixture of grains of minerals in varying proportions.

Syenite.—In hunting for specimens of granite among boulders, you will frequently see representatives of another rock which at first sight you will probably mistake for granite. This rock is called syenite. While it contains feldspar—frequently pink in color—and other minerals similar to those found in granite, quartz is not one of the essential constituents. In other words, syenite may be considered to be a quartzless granite. One should be careful not to mistake grains of white or gray feldspar for quartz.

Gneiss.—Both granite and syenite are massive rocks, that is, they do not normally have a bedded or layered appearance. You will find boulders, however, which, while they contain the same essential minerals as granite and syenite, possess a different structure, the constituents of the rock being arranged more or less crudely in lines. These varieties of granite and syenite are known as gneiss. A rock possessing the mineralogical composition of a granite or a syenite and having this layer-like structure is known as a granite-gneiss or a syenite gneiss (Fig. 4).

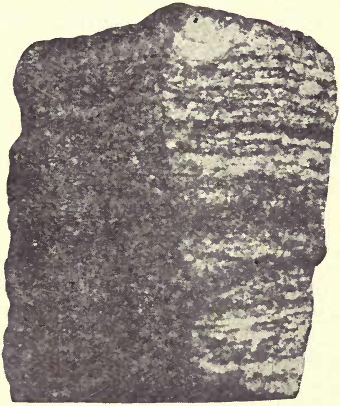

FIG. 4.

Specimen of Gneiss, showing the characteristic layer-like structure. (One-half natural size).

In your search among the boulders you will come across certain rocks which are like granite and syenite as regards the average size of their constituent grains and their massive structure, but which possess a different mineralogical composition. The colors of such rocks are usually darker than those of granite and syenite. It will be well for you to collect specimens of these massive rocks for future study. We shall describe them on later pages.

While most rocks are composed of two or more minerals, there are a few which contain only one essential constituent. Sandstone, for example, is an aggregate of quartz grains. When pure, this rock is, therefore, similar in chemical composition to a mineral. Since, however, it is an aggregate of grains, and occurs in large masses which make up an important part of the earth's crust, it is called a rock. It is not difficult to distinguish most substances which are properly rocks from those which should be called minerals. On account of the fact that there are no hard and fast lines in nature, it is impossible, without drawing an arbitrary line, to give a definition which will fit all cases.

In order to explain more fully what is meant by the name mineral it may be said : "A mineral is any natural substance occurring apart from the bodies of plants or animals and having, theoretically, a definite chemical composition." Most minerals show a tendency to assume definite forms, bounded by planes. These forms are called crystals (Fig. 1). Substances such as petroleum which are sometimes classed as minerals cannot be indicated by a chemical formula, and are therefore not minerals in the strict sense. A few minerals do not possess a crystalline structure, and hence are said to be amorphous.

The reader who has no knowledge of chemistry will understand from the following what is meant by the expression "definite chemical composition" used in the definition. A certain mineral, which will be described on another page, always contains, theoretically, 70 per cent. of iron and 30 of oxygen by weight. Its composition, by weight, is therefore said to be definite or unvarying. The composition of all minerals is as definite as is that of this one. On the other hand, we have seen that the composition of rocks is more or less variable. While granite, for example, always contains quartz, this substance may be present in varying amounts. Rocks can then be compared to mechanical mixtures, while minerals, unless they are composed of only one substance, are chemical compounds, that is, they are of definite or unvarying composition.

SAND AND CLAY.

Technically, sand and clay are rocks, although in the popular sense the name rock is applied only to compact materials.

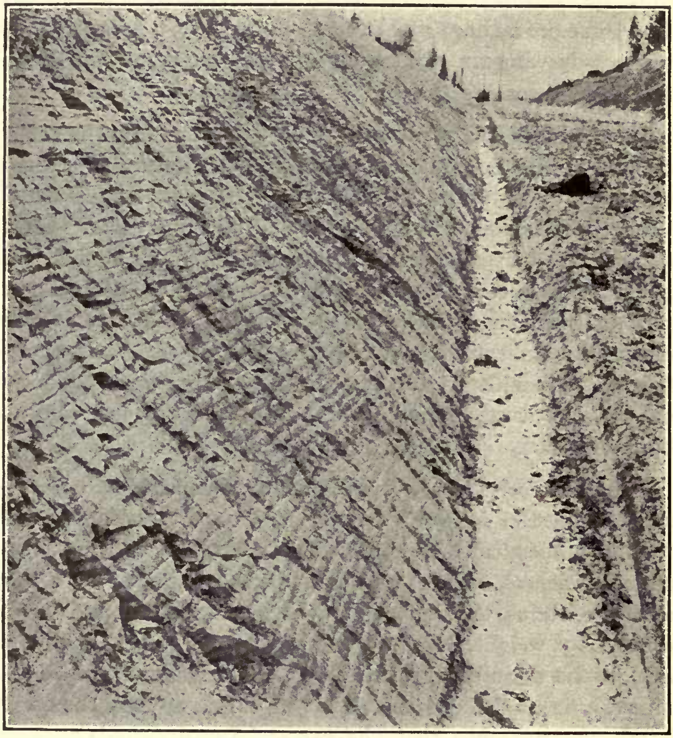

FIG. 5.

Bedded Clay along railway near the shore of Lake Temiskaming, between Haileybury and New Liskeard, Ont.

It will be seen that everyone has facilities in his own neighborhood for the practical study of rocks. In all districts there are exposures of clay, sand, gravel, limestone, or other varieties. Let us visit some of these, and thus make our study practical. It is hoped that no one will confine his attention merely to reading a printed book when the great book of nature lies open before him.

Let us first visit an exposure of clay, such as a bank or a pit from which material is being taken for the manufacture of bricks, tile, or cement. Does the clay occur in the form of a mass, or does it show a layer-like or bedded structure? A freshly-cut face will show bedding more distinctly than one which has been exposed to the weather (Fig. 5). If there are boulders in the clay it may show a very crude bedding, if any (Fig. 6). Notice how the clay, if moistened, can be

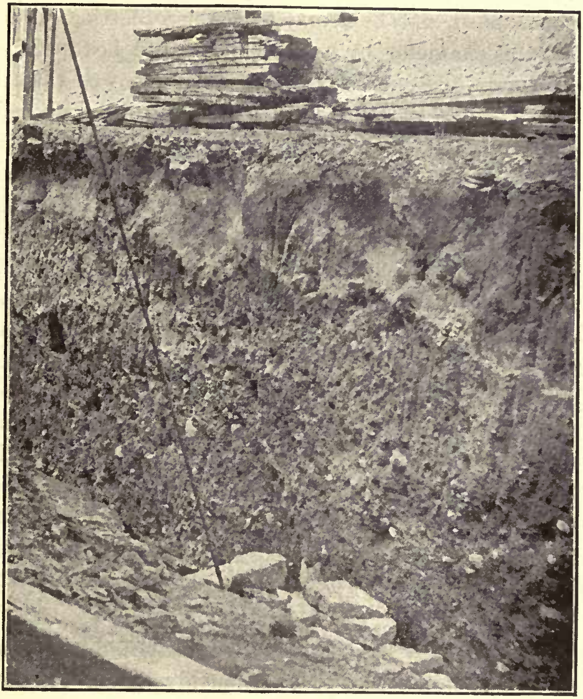

FIG. 6.

Boulder Clay on the face of an excavation at Ottawa, Ont.

[Dr. H. M. AMI, G.S.C.]

kneaded in the hand. This character is called plasticity. If you visit a brick-making plant, observe how the clay is moulded into bricks. Sand is added to some clays to prevent the bricks fusing and shrinking when heated. Powdered, burned brick, unlike the clay from which it was formed, will, when moistened, not be found to become plastic. The clay has lost this character by being subjected to heat. The red color taken on by some bricks in burning is due to the oxidation of the iron in the clay—heat causes it to take up oxygen from the air. If there is little iron or much lime in the clay, the burned bricks will be cream-colored or white. The lime will be in the form of carbonate, and its presence can be detected by the fact that the clay effervesces in acid. Clay of varying degrees of compactness is found in nature. Beds of the material are frequently buried under a great thickness of sand, gravel, or other deposits, and are thus subjected to pressure which induces compactness, just as the brick machine does. Heat is generated by pressure, and if the latter be very great, such as is produced by natural agencies, which we shall describe later, the clay is changed as much in character as if it had been burned into brick. The highly altered form of clay found in nature is known as slate, a rock which is in common use. If powdered slate be moistened with water, it will be found that, like burned brick, it possesses no plasticity.

In examining clay banks or pits, you may find some curious masses or nodules, which are commonly called concretions (Fig. 7). Some of them may simulate shells or other animal remains. The more curious of them have been called fairy stones.

The loose beds of sand which you may see in most localities are changed into the compact rock known as sandstone by pressure and cement substances, which will be described. Ordinary sand will be found on examination to consist essentially of grains of white or slightly colored quartz. If examined carefully, the grains, in some sand, will be seen to be well rounded, while in others they are angular. Can you give any reason for this difference in the character of the grains? Get some sand which is used in mortar. Are the grains round or angular?

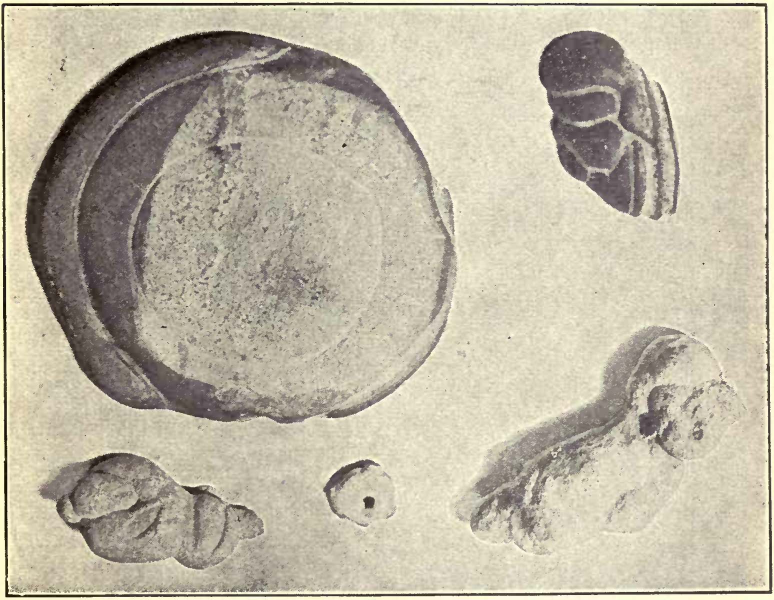

FIG. 7.

Concretions. (About one-half natural size.)

Examine the sand on some shore. See if you can find any which contains numerous black grains. If so, dry a little of the sand in the sun or by artificial means, and then stick a magnet or a magnetized knife-blade into it. If it is the black mineral which is commonly found in sand, it will be attracted to the magnet. This mineral is an oxide of iron known as magnetite. You will frequently find grains of a pink or reddish mineral associated with magnetite in sand. These are the mineral garnet. Both garnet and magnetite will be described on another page. Minute scales of mica occur in some sand.

CONGLOMERATE AND BRECCIA.

When beds of gravel or boulder deposits become consolidated the resulting compact rock is known as conglomerate (Fig. 8).

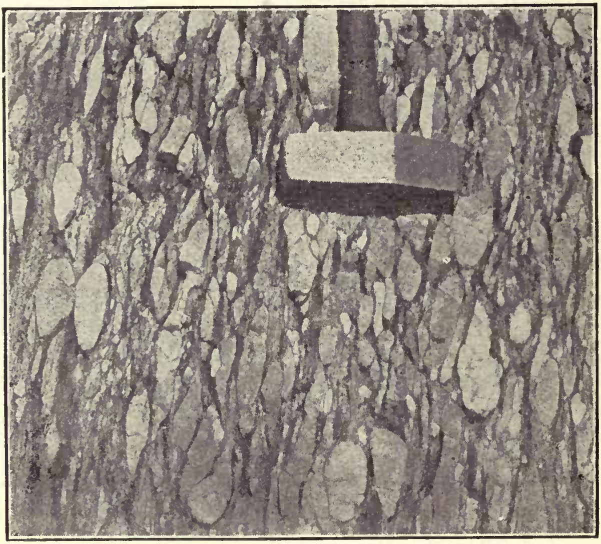

Fig. 8.
Conglomerate.

If the fragments in such a rock are angular instead of being rounded, the rock is called breccia (Fig. 9). Many compact limestones can be seen to be made up of fragments, which in some cases consist chiefly of the shells of small animals (Fig. 10).

If there are no quarries in your neighborhood, try to find boulders of sandstone, conglomerate, and limestone. Get as many varieties of each as you can. Specimens of breccia are not obtainable in some districts. A beautiful rock, known as jasper conglomerate, occurs in many places in northern and northwestern Ontario. It consists of pebbles of quartz and red jasper firmly cemented together. Boulders of it are found in the southern part of the province and in some of the states immediately to the south of the great lakes. If you live in this territory you are likely to find some of these

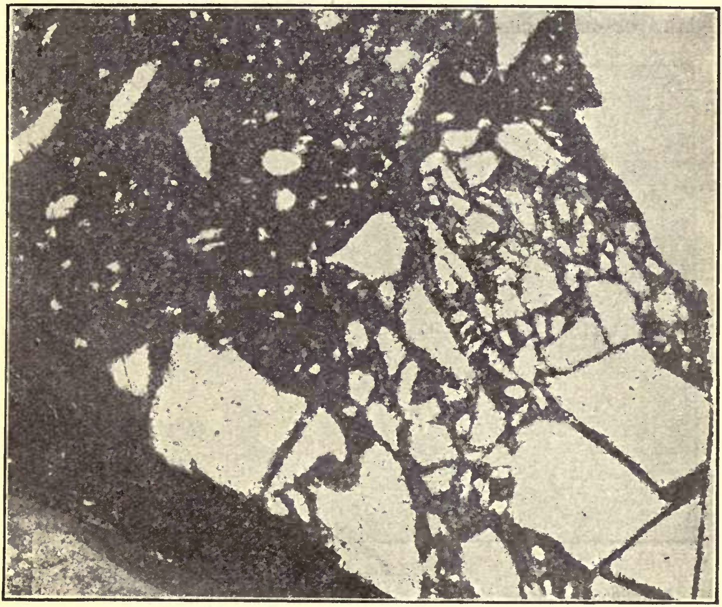

FIG. 9.

Breccia from the shore of Lake Temiskaming, near Haileybury, Ont. The angular fragments of light-colored rock are cemented by fine-grained, dark material.

boulders by careful searching. Can you explain why conglomerate is sometimes called pudding stone?

If you cannot find a specimen of conglomerate you will probably be able to see an artificial material, concrete, which resembles it closely. You can make a sample of this artificial conglomerate by mixing a few pebbles with moistened Portland or other cement, and letting the mass harden, or the pebbles can be mixed with wet clay. In the latter case the mass will harden if dried slowly. Small pebbles should be used.

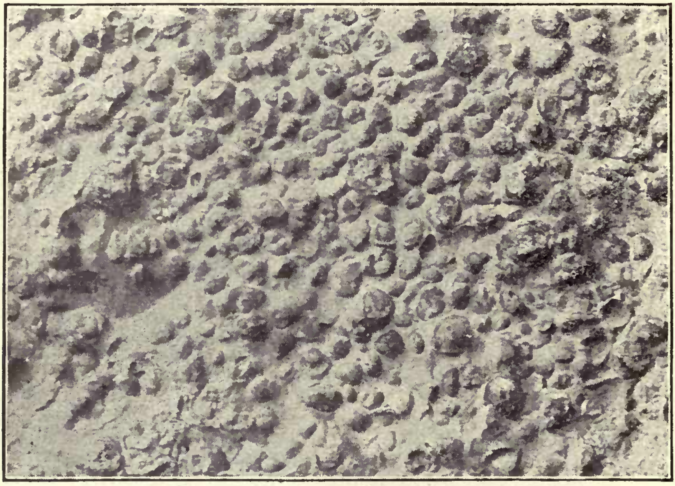

FIG. 10.

Limestone containing numerous small shells, Beachy Island, Lancaster Sound.
[Mr. A. P. Low, G.S.C.]

MARKINGS ON ROCKS.

There are other points in connection with these rocks which you may observe when examining them in the field, such as the marks made by waves on the surface of sand along a shore. These are known as ripple marks (Fig. 11).

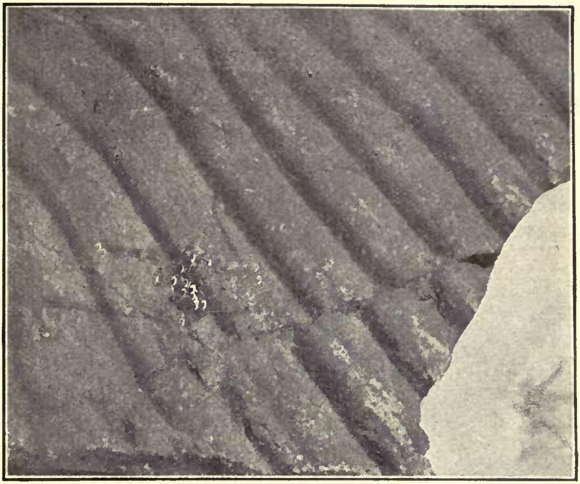

Fig. 11.

Cast of Ripple Marks in clayey sandstone, from the coal fields of Nova Scotia. It will be seen that the specimen has been broken across and recemented, one side being slightly moved from its original position.

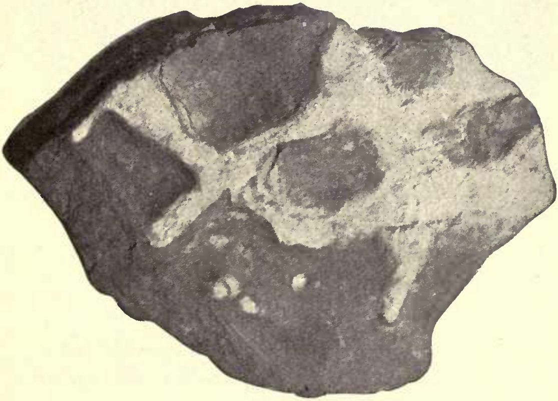

Fig. 12.

Ancient Mud Cracks in clay (shale). The material filling the cracks is lighter in color than the clay.

Somewhat similar forms are produced by wind on sandy surfaces. In very dry weather you will find that surfaces of clay deposits have become cracked through shrinkage of the mass. Such structures are known as mud cracks (Fig. 12). Rain drops, when falling on surfaces of loose, fine-grained sand or clay produce characteristic pittings.

Markings, such as those which we now find on unconsolidated rocks, are frequently found in compact sandstone and clay rocks formed ages ago. They teach us interesting facts about past times. We learn, for instance, that the showers of rain during early periods of the earth's history were similar to those which fall in our own time, since they produced like effects on sand and clay. From the tracks preserved in certain old sandstones, we learn something of the character of the animals which prowled along ancient shore lines (Fig. 13). A slab of sandstone, which the writer has seen, from the coal mines of Nova Scotia, bears the footprints

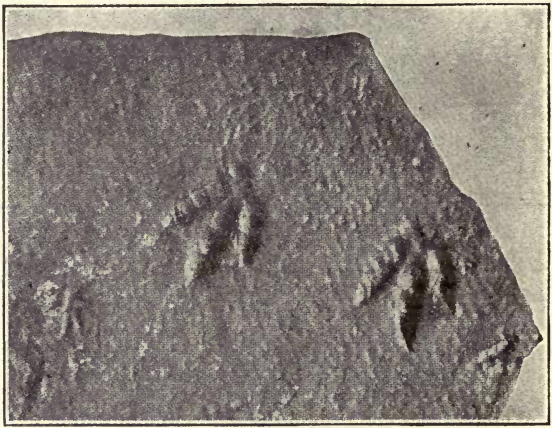

FIG. 13.
Tracks of an extinct reptile in sandstone.

of an extinct animal, apparently about the size of a cat. The tracks show that the animal walked quietly along for a time and then made a sudden spring, either to capture prey or to escape from an enemy. The footprints preserved in some rocks are as numerous as are those to be seen in the soft earth of a barnyard.

Most of these markings which we now find preserved in compact rocks have been made along the shore of an ocean. During low tide the materials containing footprints and ripple-marks become more or less hardened by drying, so that the impressions cannot be easily destroyed when again covered by water. Moreover, as the water rises on the shore, it tends to fill in the depressions with a fresh supply of sand or clay carried up by it, and thus the markings are preserved.

It is not difficult to reconstruct ancient geographical boundaries, such as shore lines, by a study of the rocks. You will notice that, along present shores, the coarser gravel is not carried so far by the water as the sand and clay. Gravel and sand are essentially shallow water deposits, if there is no current to interfere with their deposition, while the fine particles of clay tend to remain in suspension and may find a resting place at a considerable distance from the shore.

FOSSILS AND LIMESTONE.

In examining clay banks or sand pits you will frequently find shells of snails, clams, and other small animals, and at times the bones or skeletons of larger animals. It is shown on following pages that water percolating through rocks carries mineral matter such as silica and calcium carbonate in solution. When such water comes in contact with the remains of animals and plants in sand, clay, or other rocks, out of contact with the air, it tends to bring about changes in them, sometimes replacing the material in the remains, particle by particle, with mineral matter. In other words, the remains become petrified or turned into stone. Petrified shells, bones, and other remains, especially if they represent extinct forms, are known as fossils. Bones and shells are, however, frequently preserved in the rocks without having undergone much change. The name "fossil" is applied to them as well as to the petrified varieties. Ancient markings on rocks, such as tracks, rain prints and ripple marks, are also known as fossils. Originally the term fossil had a wider meaning and included minerals. It was applied to anything dug out of the earth.

Many animals extract calcium carbonate from water to form their hard parts. On the death of such organisms, these parts resist decay, and in course of time by their accumulation, large masses of shells and other structures are formed. Such masses are classed as rocks. Since they are composed essentially of calcium carbonate they are known as limestone. Calcium oxide is usually called lime. The mineral to which the name "calcite" is given is composed of calcium carbonate.

Certain limestones are built up of shells and other calcareous remains loosely cemented together. It will be readily understood that such a mass of material will not stand any great amount of pressure, such as it would be subjected to if overlaid by beds of clay or sand, without many of the shells and other calcareous remains being reduced to fragments. Hence we find that many limestones, which at one time were built up of shells in a perfect state of preservation, now show little evidence of their origin. Chemical changes are also brought about in such limestones through the action of water. Shells may be completely dissolved and replaced by other material from solution. Limestones are, however, great storehouses for fossils. Shells and other hard parts of animals are frequently preserved in such a way as to show all the delicate markings and structures of the originals.

Great use is made of fossils in geology. We learn from them that animals and plants quite different in character from those now living were in existence at certain periods of the earth's history. Limestones, sandstones, and other fragmental rocks laid down by water at different periods, are found to contain characteristic fossils. We are thus able to classify rocks according to their ages. From the character of the fossils enclosed in the rocks it can be proved that climates different from the present have existed in various regions.

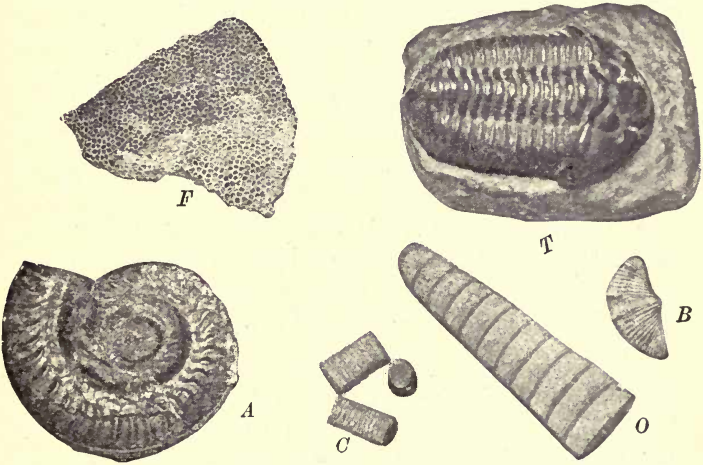

Fig. 14.

Fossils of popular interest. F, favosites; B, "fossil butterfly"; T, trilobite; C, fragments of crinoid stems; O, orthoceratite; A, ammonite. (Less than one-half natural size.)

Visit quarries and see if you can find a few fossils. You will be able to get them in some of the boulders of fragmental rocks in your neighborhood, if you have not access to quarries.

Many farmers, quarrymen, and others can assist you in your search for fossils. They are frequently interested by the forms they find in the rocks, especially if these resemble living animals or plants. In regions where there are outcrops of the older fossiliferous rocks, which will be described later, such as the territory which surrounds Lakes Ontario and Erie and the greater part of Lake Huron, there are a number of fossils of great popular interest. If you live in one of these regions you will have little difficulty in obtaining specimens of one or more of the fossils about to be mentioned. There is a type of extinct coral which is popularly mistaken for fossilized "bees nest" (Fig. 14). The scientific name of this coral is "favosites" (*favus*, honeycomb). The shell of a certain small mollusc is often called a "fossil butterfly." You may be able to get a specimen resembling this rather closely if you cannot get the exact form.

The fossils which have probably attracted the greatest attention from quarrymen are known as trilobites. They belong to an extinct group allied to the horse-shoe crab and crayfish of existing nature. Some of these fossils bear a resemblance to bull frogs. Hence you will probably find the quarrymen so naming them. Fragments of the stems of crinoids—stone lilies—have been used for beads. Then there is a group of mollusca, whose hard parts are mistaken for fossil snakes or the backbones of fishes. Some of these animals have straight, and others coiled shells. One of the most common of these, which sometimes reaches a length of several feet—although usually only a few inches in length—is known as the orthoceratite (straight shelled). Another form is the ammonite, which has a coiled shell. There are other fossils which have long excited popular interest, but those mentioned will give the reader an idea of the mistakes which are commonly made concerning the character of extinct animals. We shall have something further to say about fossils on later pages.

CLASSES OF ROCKS.

We have said that clay is changed by pressure, accompanied by heat, to slate. Sand and sandstones, when subjected to these agencies, become more compact and tougher. The rocks produced from them are known as quartzites. When limestones are similarly treated they become more compact and brighter, being changed to what is known as crystalline limestone or marble. Slate, quartzite and crystalline limestone, being altered or changed rocks, are usually put in a class which is known as that of the metamorphic rocks. Since ordinary, unaltered sand and sandstone, conglomerate, clay or shale, and limestone are built up of fragments of minerals and rocks, they are commonly classified as the fragmental or sedimentary rocks. The name aqueous is also applied to them, owing to the fact that they are usually laid down by water. Granite, syenite, and others, which we have spoken of as the massive rocks, can be proved to have consolidated from molten material. They are, for this reason, placed in a third class known as that of the igneous or heat-formed rocks.

On the basis of origin we can therefore divide rocks into three great classes :—

1. Aqueous or Fragmental. 2. Igneous. 3. Metamorphic or Altered.

The reader will understand from what has been said that the members of any one class differ from one another chiefly in the minerals which they contain. In the igneous or massive class, for example, we have shown that the difference between granite and syenite is in the presence of quartz, as an essential constituent in the former, and its absence in the latter. Similarly in the aqueous class, sandstone is composed of quartz and limestone of calcite.

The conglomerate represented in fig. 8 has been subjected to pressure, and belongs more properly to the metamorphic class than to the aqueous. It is seen that all the pebbles have their longest diameter in one direction. This is due to great and long continued pressure which has drawn out the pebbles without fracturing them. It will be readily understood that similar effects may be produced by pressure on the grains of igneous rocks. Thus granite and syenite at times, owing to this cause, take on a crudely bedded or layer-like form and are changed to granite-gneiss or syenite-gneiss. Other massive rocks are similarly affected. When the pressure has been very great, thin layers or laminæ are produced in igneous rocks along which they split or separate more or less easily. A rock possessing this structure is known as a schist. In addition to quartzite, slate and crystalline limestone which we have mentioned, the metamorphic class embraces, therefore, two other members, gneiss and schist.

It may be added that certain aqueous rocks also give rise to gneiss and schist when subjected to pressure and other agencies.

The reader will not be able, without a great deal of practice, to name some of the rocks with which he meets. For practical purposes much will be achieved if he can satisfy himself as to what class a specimen of the material in an outcrop belongs.

Try at first to get in your collection one or more specimens of each of the three great classes. Let limestone or sandstone represent the aqueous class, granite the igneous, and slate or marble the metamorphic.

ACTION OF WATER AND OTHER AGENTS.

Gravel deposits and beds of sand frequently become consolidated without the action of pressure. Some substance such as calcium carbonate, silica, or oxide of iron is deposited between the fragments by circulating water. They are thus gradually cemented together. That some waters contain a considerable percentage of these substances in solution can easily be proved. It can be observed in every household that calcium carbonate, so-called lime, gradually accumulates in tea kettles in which only what is generally known as pure water is boiled. The calcium carbonate must therefore be in solution in water of this kind. Kettles in which well or spring water is boiled especially in limestone regions, usually accumulate more solid material than those in which water from large lakes is used. Similar accumulations are found in steam boilers. The reader may live in a district in which this solvent action of water is made much more evident. For instance, he may be acquainted with springs which deposit calcium carbonate or silica as their waters issue from the earth. Leaves, twigs and other objects which fall into such waters frequently become coated especially with calcium carbonate. Around the hot springs of the Yellowstone Park and elsewhere the waters deposit much silica. Salts of iron can be tasted in some well waters. It is thus not difficult to understand where the three cement substances come from, which we frequently find binding together the fragments in sandstones, conglomerates and other rocks. We likewise learn how cracks or fissures in rocks come to be filled at times with silica in the form of quartz, or with calcium carbonate, and other substances to produce so-called mineral veins (Fig. 15).

The fact that water tends to dissolve rocks is not so easy to prove as is the fact that it carries certain substances in solution. This is owing to the slowness with which solution takes place.

It is not difficult, however, to prove that rain water contains much less material in solution than that which runs off the surface in streams and rivers. We thus learn that the water in soaking through the soil or running over the surface dissolves mineral matter. The rounded surfaces and enlargement of the cracks in limestones exhibit the solvent effects of

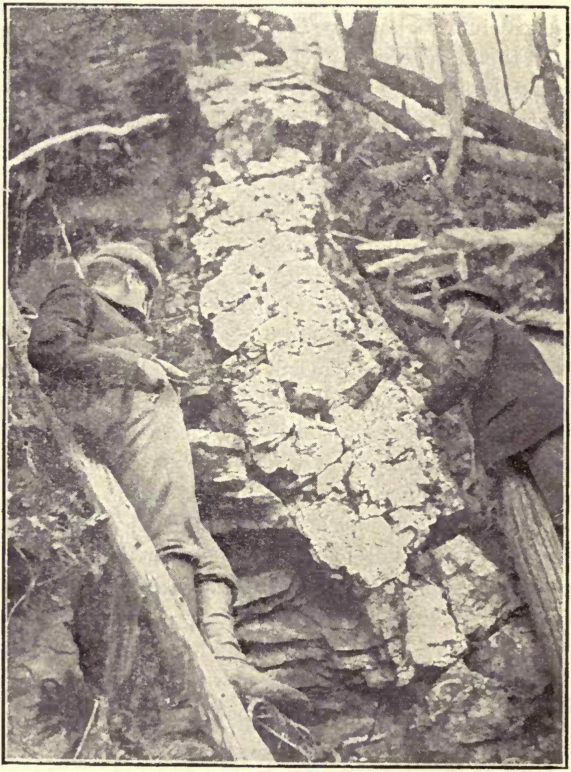

FIG. 15.

Quartz vein, Poplar Creek, B.C.

The vein shown in the illustration is exposed on a steep hill side. The men are standing on the rock at the sides of the vein. The quartz is gold-bearing.

[Prof. R. W. BROCK, G.S. C.]

water, as well as do the underground channels and caverns frequently found in these rocks (Fig. 16). Inscriptions on tombstones made of this rock also become gradually obliterated,

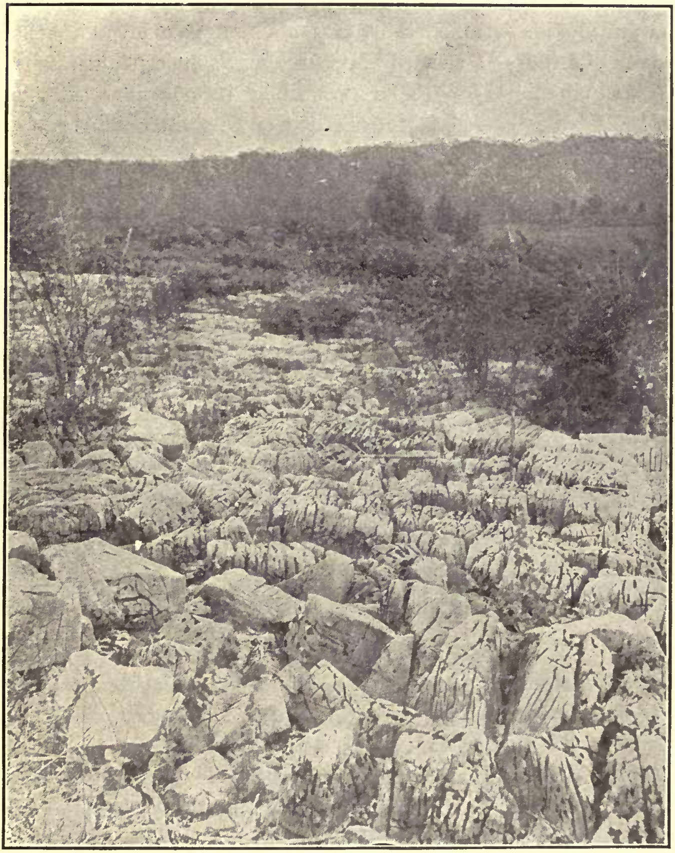

Fig. 16.

Surface of limestone on Barriefield common, Kingston, Ont., showing the destructive effects of water, frost and vegetation.

[Dr. H. M. Ami, G.S.C.]

as may be seen by comparing those on stones which have been erected some years apart.

The solvent effect of rain water on such rocks is due to the gases which it dissolves in its passage through the atmosphere. Carbon dioxide is exhaled by animals, and is evolved in the burning of fuel. Its supply is consequently being continually renewed in the air. This gas when in solution attacks especially the lime and the alkalies of the minerals in rocks and carries them away in solution as carbonates (see feldspar, page 92). In the burning of coal, more or less sulphur dioxide gas passes into the air along with carbon dioxide, and it has a powerful solvent effect on mineral matter. It has been observed, for instance, that the inscriptions on tombstones in the neighborhood of cities become dimmed more quickly than on those in less populous districts. The oxygen of the air in the presence of moisture is also a rock destroyer. It attacks especially the iron, which is found in nearly all rocks, and combines with it. Its effects are strikingly seen on rocks which contain iron sulphide. Such rocks break down rapidly, oxide of iron and sulphur dioxide or sulphates being formed. That dry air has little power to bring about oxidation is shown by the fact that iron or steel instruments when kept from moisture do not rust. On the other hand, if they are left in a damp place for a short time they rapidly become oxidized. Water is thus shown to play an important part in the destruction of rocks by chemical means. That its mechanical effects are also very great is apparent to every observer. We see mud and sand carried along by streamlets after a shower. The banks and beds of ditches and streams are cut down, and roadways, especially if hilly and composed of sand or clay, need to be repaired from year to year. Rapidly flowing streams or rivers frequently transport pebbles or even boulders. The reader, if he lives near the shore of a lake or ocean, can see the powerful mechanical effects produced by waves. It will there be made more apparent to him than by stream action, how fragments of rock are rounded and ground to granular or powdery material. The pebbles and grains not only abrade one another, but they also wear away the solid ledges against which they may be rolled. At times when there is a heavy sea along a cliff, the pebbles may be hurled against it with such force that they have the effect of artillery (Fig. 17).

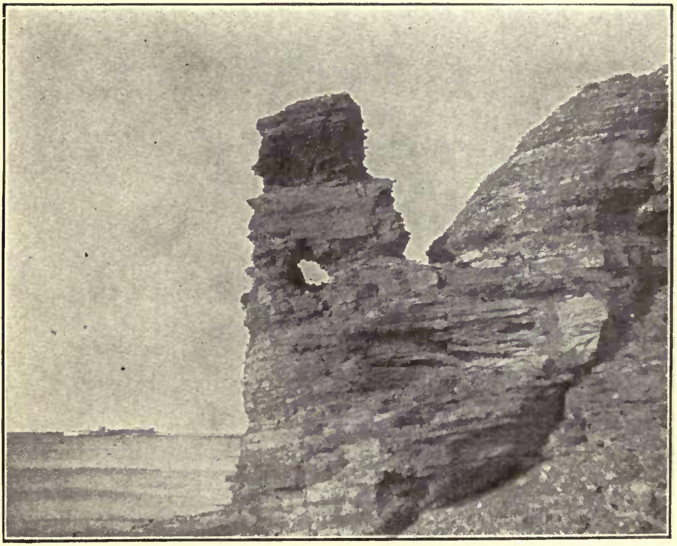

FIG. 17.

Shales weathered by storm and wave action, Arisaig, Antigonish County, Nova Scotia.

[DR. H. M. AMI, G.S.C.]

Where an eddy occurs in which gravel and boulders are kept in gyration round holes, known as pot holes, are frequently cut in the rock of a stream bed (Fig. 18). These holes are sometimes mere cup-like depressions; at others they are like huge caldrons. Water falling through a crack in a thick ice-sheet and carrying stones with it may produce similar effects.

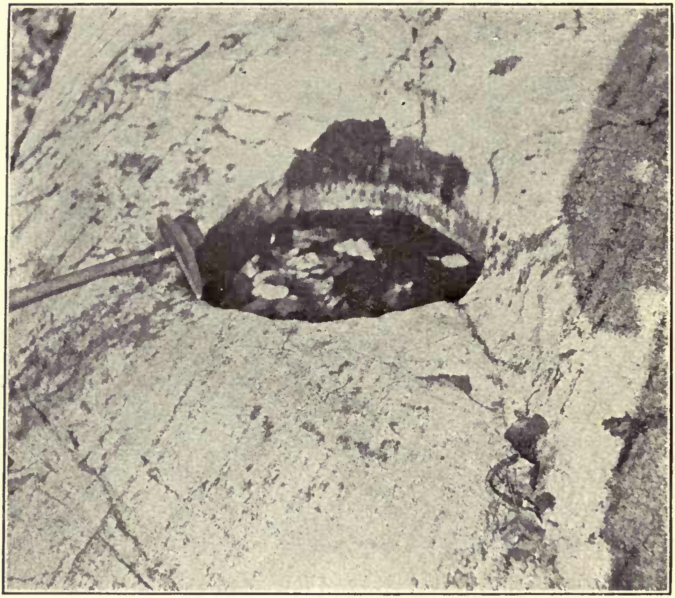

FIG. 18.

Pot Hole, three or four feet deep, in a glaciated surface, Mattawa river, Ont. The hole is nearly filled with water and fragments of rock.

In northern countries the highly destructive effects brought about by ice on rocks is apparent to every one. Water freezing in cracks and crevices and expanding acts like a wedge, splitting and prying pieces off. Glaciers also, which may be briefly defined as rivers of ice, flow slowly down from mountain tops and, with the boulders or angular fragments frozen into their masses, striate, groove, polish and cut away the rocks over which they pass, carrying the loosened material onward (Figs. 19, 20)

This brief description of the effects produced on rocks will, it is hoped, suffice to convince the reader that water is an important destructive agent, and that there is what may be called death and decay in the inanimate world. He will also now understand how the loose materials, sand, gravel and clay, among which is embraced soil, are derived from compact rocks, and by what means they are re-cemented into the compact form. It should be noted that water has not only

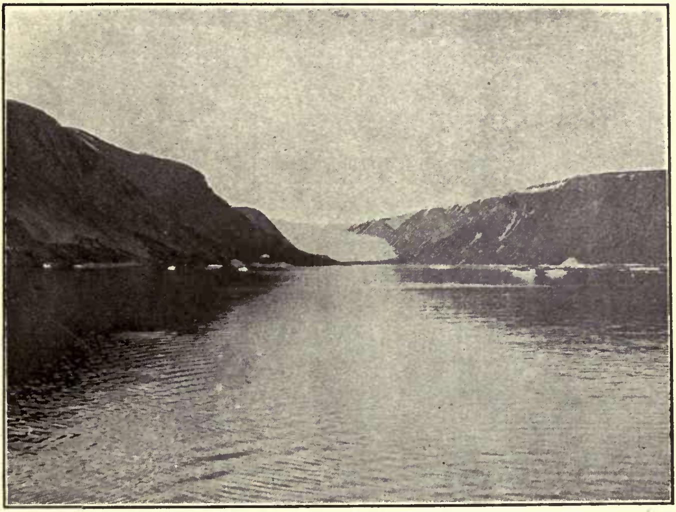

FIG. 19.

A Glacier flowing to the sea from interior ice-cap. Small fiord at Pondo Inlet, North Baffin Island.

[Mr. A. P. Low, G.S.C.]

destructive effects, but that it has reproductive effects as well. When the sand, gravel and clay are deposited by water, rocks are reproduced.

We have seen that sand and some clay occur in well defined beds (Fig. 5). If the reader does not understand how this bedded structure is produced, let him study the method of deposition in some pool or at the mouth of some streamlet. He will there see the sorting action which water has on material of different degrees of fineness. Or he can throw a couple of handfuls of a mixture of fine gravel, sand and clay, into water, preferably in a large glass vessel, and observe the layers formed when the material has settled.

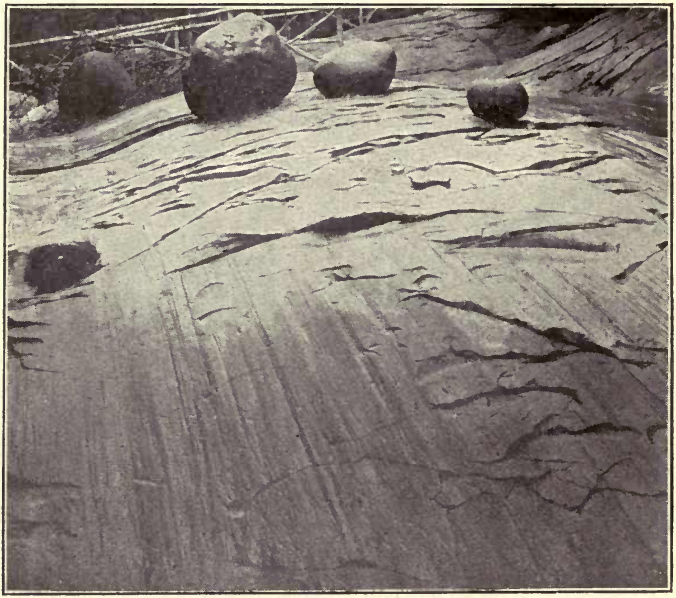

Fig. 20.

Rock surface striated by a glacier.

While, as has been shown, air free from moisture has little chemical effect on rocks, its mechanical effects can be seen in any locality. Wind transports dust and sand and, at times, larger fragments of rock. Sand hills or dunes are formed, and important changes are brought about on the surface of the earth through this agency (Fig. 21). In some districts, at certain periods of the year, the temperature during the day is much higher than that during the night. Sudden expansion and contraction is thus brought about on the surfaces of rocks causing blocks or slabs of considerable size to be broken off. Masses of rock have also been broken up by lightning.

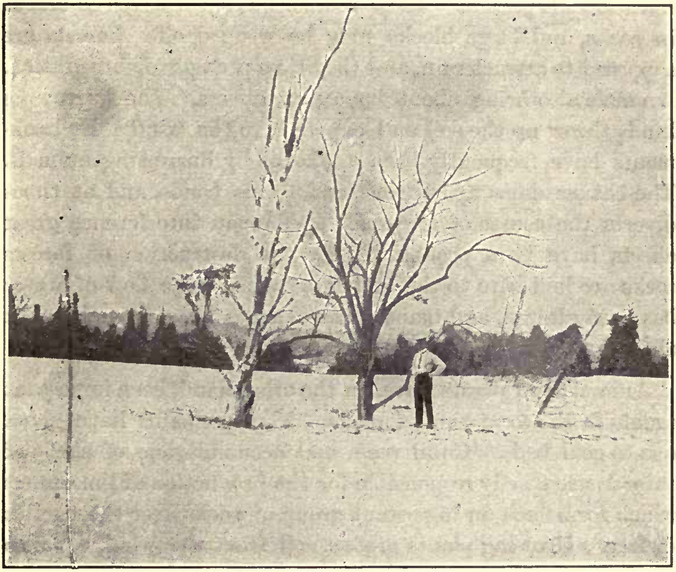

FIG. 21.

Part of Sand Dune, encroaching on a forest. The white sand has buried the trunks of the trees—white birch on the left and maple on the right, near the man—to a height of 20 feet. Prince Edward County, Ont.

[MR. M. B. BAKER.]

Animals and Plants.

Animals and plants, as well as water and air, play an important part in the breaking down of rocks. Plants tend to keep surfaces moist and thus produce destructive effects, and on their death and decay give rise to compounds which have solvent powers. Their roots are often inserted in cracks in rocks, and large blocks may be wedged off. Forests are supposed to attract rain, and they thus promote disintegration. Animals also bring about important effects. The burrowing kinds throw up the soil and expose it to the wind. Embankments have frequently been weakened by burrowing animals. The beaver dams up streams and forms ponds, and at times diverts the course of streams. By human interference great effects have been produced. By the destruction of forests rocks are laid bare to the action of wind. The flow of water has been altered, and many other changes have been brought about by man.

Animals and plants have, on the other hand, been important agents in the formation of rocks. Plant remains have given rise to coal beds. Coral reefs and accumulations of shells of animals are chiefly responsible for the production of limestones which form such an important group of rocks over the earth's surface. Growing plants protect soil from the wind, equalize the flow of water, and have other protective effects.

Volcanoes and Earthquakes.

In addition to the agents—water, air and life—which bring about the decay, or what is called, in a general way, weathering, of rocks at the surface of the earth, there are others whose source is within the crust. These include chiefly volcanoes and earthquakes. The name "volcano" is applied, typically, to a conical hill or mountain (built up mainly of erupted material), from the summit of which hot vapors, fine and coarse fragments of rock, and streams of molten matter are intermittently expelled (Fig. 22). There is usually a cup-shaped depression, known as a crater, at the top of such hills, which is connected by means of a pipe or chimney with a molten interior. The eruptions, often accompanied by violent explosions, appear to be due to the expansion of water-vapour and other gases. As few of our readers have an opportunity of seeing active volcanoes, we shall content ourselves with the foregoing brief description, and shall refer those desiring fuller accounts to some of the numerous text-books of geology in which the phenomena are described. It may be added, however, that in many districts the former presence of active volcanoes can be proved. For this reason a knowledge of

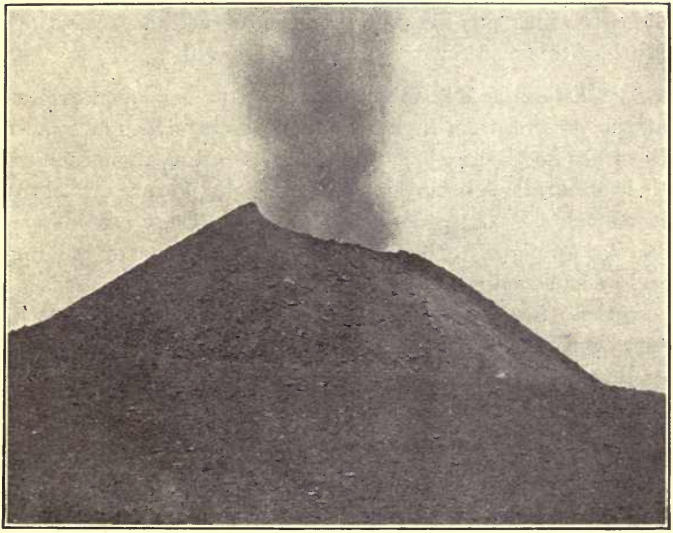

Fig. 22.

Cone of a Volcano, built up of erupted, fragmental material.

their effects is important. The molten matter which has flowed from them has given rise, at times, to wide-spread sheets of rock which have greatly changed the appearance of the surface. Knowing what the characters of the rocks now produced around volcanoes are, we can easily recognize these ancient flows. The fragmental material thrown out from volcanoes, which may be in the form of fine dust, called ash, or in blocks of various sizes, is to be found in many districts, thus proving the presence of volcanoes ages ago. Much of this material is more or less glass-like.

The disturbances in the crust known as earthquakes occur at the present time in nearly all districts, although some of them are so slight that they are not ordinarily recognized, their occurrence being detected only by means of delicate instruments. These disturbances in the crust are in some cases so strong as to bring about the destruction of buildings and other structures. In the more violent kinds cracks are sometimes formed in the crust and can be recognized at the surface of the ground. Earthquakes are due chiefly to the cooling and shrinkage of the crust, but may be produced by the falling in of the roofs of caverns, and by other means.

In addition to the effects produced on rocks by the agency of volcanoes and earthquakes, there are movements in the crust which are so gradual as to be almost imperceptible. Through long-continued and enormous pressure the rocks are folded and warped, often on a large scale, thus causing some parts of the surface to rise and others to sink. The coast of Newfoundland, for example, is gradually rising while that of Greenland is as gradually sinking; the coast in one place being on the apex of a great fold, while in the other it is in a trough-like depression. Mountain ranges and table-lands are produced by such movements. Hence we see why marine fossils are, at times, found high above the present sea level.

From this brief reference to the agents at work on the earth's crust, we see that rocks are constantly undergoing change. Material is being broken down in one place, and redeposited in another. Rock matter is brought from the interior to the surface of the earth. Cracks, folds, and other structures are being formed (Figs. 75, 79). Minerals which, as we have seen, are the units of which the whole crust is built up, are thus found to be derived from various sources and to occur under many conditions.

PART II

A.—PHYSICAL CHARACTERS OF MINERALS.

Some of the chief physical characters of minerals depend upon the arrangement of their molecules, or, in other words, upon their crystallization. The term crystal has been briefly explained on a preceding page.

Crystals.—There are six systems of crystallization, to one or another of which all crystals belong. Substances which are not crystalline, that is, their molecules are not arranged in any definite order, are said to be amorphous[1]. Glass is one of these. The term crystal is sometimes, therefore, wrongly used in such expressions as "crystal glass" or "clear as crystal," meaning a bright, transparent substance. While some crystals are transparent, such as those of quartz and calcite (which may, however, be opaque) and the gem varieties of the diamond and other minerals, the majority are opaque or at times translucent.

A knowledge of crystallography, the science of crystals, is not only of value in the determination of minerals, but use is also made of it in chemistry. Many salts prepared in the laboratory can be identified by the forms in which they crystallize when the solutions, in which they are dissolved, evaporate under favorable conditions.

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[1] Certain minerals occur, at times, in *imitative* shapes; such terms as the following are then used in describing them—nodular, mossy, filiform or thread-like, dendritic or branching tree-like, reticulated or net-like, reniform or kidney-shaped, botryoidal, *i.e.*, consisting of a group of rounded prominences (from Greek *botros*, a bunch of grapes).

The Systems of Crystallization.—

1. The Isometric or Regular system possesses three axes, or imaginary lines of equal length, which cross at right angles, as shown in Figs. 23, 24.

2. The axes of the Tetragonal system, which are three in number, cross at right angles, the two horizontal ones being of equal length but longer or shorter than the vertical (Fig. 25).

3. The Orthorhombic system has three axes of unequal length which cross at right angles (Fig. 26, *a*).

4. In the Monoclinic system the two horizontal axes cross each other at right angles, while the vertical axis is inclined to one of the other two (Fig. 26, *b*). No two axes are the same length.

5. In the Triclinic system no two of the three axes cross each other at right angles. The axes are of unequal lengths (Fig. 26, *c*).

6. There are four axes in the Hexagonal system, three horizontal ones, of equal length, which make angles of 60° with one another, and a vertical one which stands at right angles to the other three (Fig. 27).

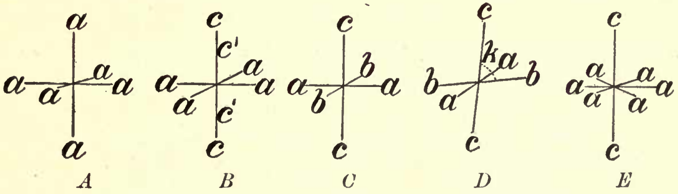

FIG. 23.

AXES OF CRYSTAL SYSTEMS.—*A*, Isometric; *B*, Tetragonal (the vertical axis, *c—c* or *c'* - *c'*, being longer or shorter than the horizontal axes); *C*, Orthorhombic; *D*, Monoclinic (the axis *c* making an oblique angle, *k*, with the axis *b*); *E*, Hexagonal. In *C* and *D* the horizontal axes *a—a* and *b—b* should be interchanged to conform with the usage adopted by many authors.

MODELS OF CRYSTALS.

The relations of the forms in each system will be seen from the figures. The reader will, however, understand these forms better if he makes models of them. Models suitable for preserving in a collection are commonly cut out of wood. Or the faces of the different forms may be made of pasteboard, glass or celluloid, and cemented or glued together. If glass or celluloid models are used, these materials both being transparent, the axes can be represented by threads within the model.

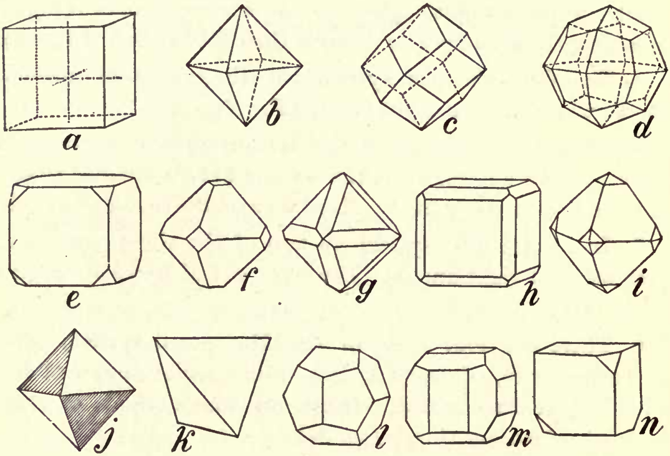

Fig. 24.—Isometric System.

1. Important simple forms:—*a*, Cube showing axes; *b*, Octahedron; *c*, Rhombic Dodecahedron (a solid with twelve rhombic faces); *d*, Trapezohedron (a solid bounded by twenty-four trapeziums).

2. Combinations of two forms:—*e*, *f*, Cube and Octahedron; *g*, Octahedron and and Rhombic Dodecahedron; *h*, Cube and Rhombic Dodecahedron; *i*, Octahedron and Trapezohedron.

3. If we consider alternate faces of the Octahedron to be suppressed, as in the shaded faces of *j*, a *half-form* with four triangular faces, known as the Tetrahedron, *k*, results. The Pentagonal Dodecahedron, *l*, is another common half-form of the Isometric system; *m* is a combination of this form with the cube, and *n* is a combination of the Cube and Tetrahedron.

For practice in making models and in studying the derivation of one form from another in a system, the author has found paraffin, such as is commonly sold in drug stores, one of the most suitable materials. It is easily cut, and the shavings and fragments can be melted into a mass and used over again.

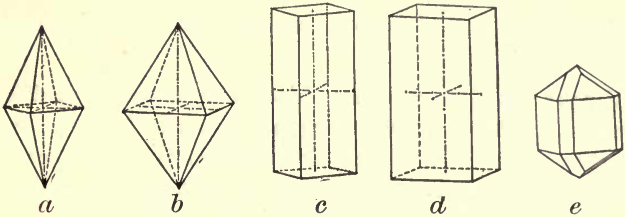

FIG. 25.—TETRAGONAL SYSTEM.

a and *b* Pyramids, *c* and *d* Prisms, owing to the position of the axes *a* is known as the pyramid of the *first* order and *b* of the *second* order. Similarly *c* is the prism of the first order and *d* of the second order. *e* is a combination of the forms *a, b, c, d*, the basal planes being absent.

ORTHORHOMBIC SYSTEM.

The forms of this system differ from those of the tetragonal system in that while the axes cross at right angles no two of the three are of the same length.

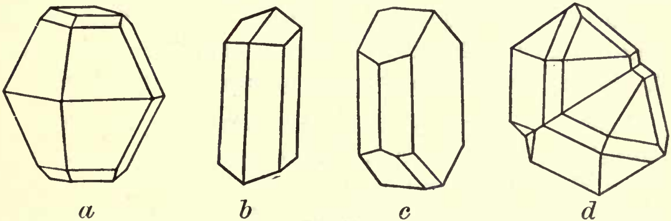

FIG. 26.

a represents an Orthorhombic crystal of sulphur. Other crystals of this system are shown in Figs. 31 and 54. *b* represents a Monoclinic crystal, and *c* a Triclinic crystal. *d* is a crystal of the Tetragonal system, which has the appearance of having been cut across and one-half revolved through an angle of 180° on the other half. Such crystals are known as *twins*, and are of not uncommon occurrence, *e.g.*, twin octahedrons. On a following page a figure of a twin crystal of feldspar is shown.

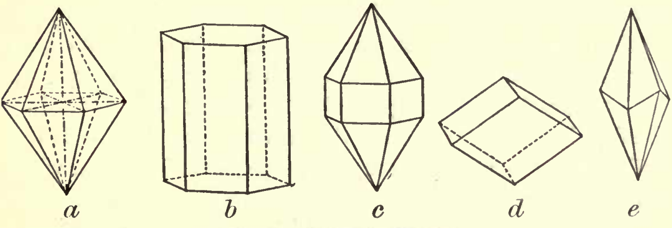

FIG. 27.—HEXAGONAL SYSTEM.

a, Hexagonal Pyramid showing axes; *b*, Prism; *c*, combination of Pyramid and Prism, without basal planes; *d*, Rhombohedron; *e*, Scalenohedron.

If nothing else is at hand one can cut a model from a potato or an apple.

For practice the reader should first try to make models of the common forms of the isometric system. Make a cube. Then cut off a small amount from each of the eight corners, being careful to remove the same amount from each corner and to see that the new planes make equal angles with each of the cube faces. A combination of the cube and octahedron is thus produced (Fig. 24, *e*, *f*). If the cutting is continued evenly on each corner the cube faces finally disappear and the octahedron results. It will be found that by truncating each of the twelve edges of the cube a rhombic dodecahedron is produced (Fig. 24, *h*). The reader should continue his experiments with models until he has learned how any form of this system can be produced from another. He should then study the simpler forms of the five other systems in the same way.

Pasteboard models can be made by using diagrams such as those shown in Fig. 28, *a–h*. Draw these on the pasteboard. Use a sharp knife and cut the inner lines, shown in the diagrams, only part way through so that the pasteboard can be bent to the required shape along these cuts. Bend the parts into the form and bind the edges or corners with paper and paste, or sew them together.

Crystals are frequently more or less distorted in nature. The reader should therefore not expect to find them as perfect in form as models which he may be shown or as diagrams usually represent them to be. A cubic crystal, for instance, may occur distorted in such a way as to resemble a crystal of the tetragonal system (Fig. 25, *d*). The lustre or aspect will be found to be the same on all the faces of the distorted cube, while that of the two end faces of a tetragonal crystal, which it resembles, is frequently different from that of the other faces. Cleavage also frequently aids in distinguishing distorted

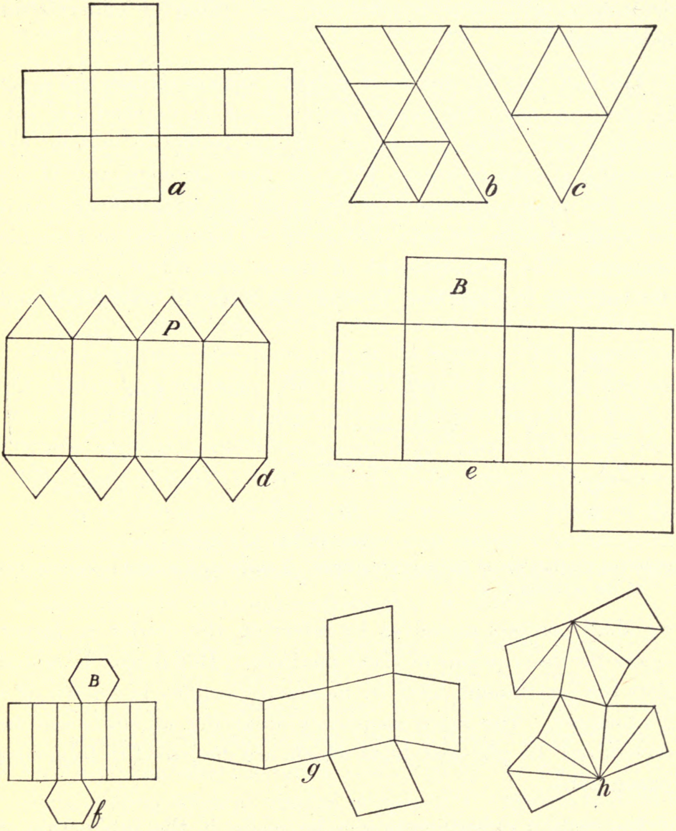

Fig. 28.

Diagrams for the Construction of Crystal Models.

Make enlarged drawings, about five times as large, of these diagrams on pasteboard and construct models according to the directions in the text.

a, Cube (Fig. 24 *a*); *b*, Octahedron (Fig. 24 *b*); *c*, Tetrahedron (Fig. 24 *k*); *d*, Combination of Tetragonal Prism and Pyramid (*P*, pyramidal plane); *e*, Orthorhombic Prism (B, basal plane); *f*, Hexagonal Prism (B, basal plane) (Fig. 27 *b*); *g*, Rhombohedron (Fig. 27 *d*); *h*, Scalenohedron (Fig. 27 *e*).

crystals, as will be seen from the description of minerals on other pages.

The fact that the angles of crystals always remain the same is, however, most commonly made use of in determining distorted forms. The octahedron of the isometric system, for example, always measures 109° 28′ over an edge, and, if we have the means of measuring the angle, this octahedron cannot be confused with the octahedrons of the tetragonal or rhombic systems. The measurement of angles and other methods of determining crystals are beyond the scope of this book, and we shall content ourselves by referring the reader to larger works for descriptions of these methods. But it may be added that the instrument used in measuring angles is known as a goniometer. The more commonly occurring minerals can be recognized by physical tests which are described in following paragraphs.

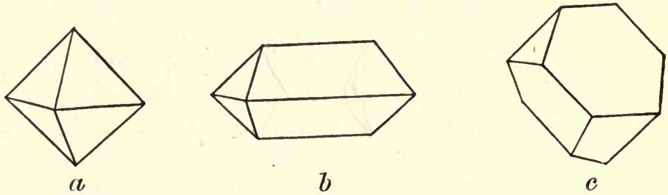

FIG. 29.

Distorted Crystals are of frequent occurrence. *b* and *c* are distorted representatives of the octahedron *a*.

Instructive experiments can be made in the production of crystals. Make somewhat concentrated solutions by dissolving one or more of the following substances, each by itself, in the form of powder in warm water—potash alum, copper sulphate, iron sulphate, common salt, nitre. Place any one of these solutions in a wide-mouthed vessel, such as a glass beaker or fruit dish, and set in a warm, dry place free from dust. It will be found that in the course of a few days, as evaporation takes place, crystals of the salts will separate out. Their growth can be watched from day to day. Suspend a piece of alum by a fine thread in a concentrated cold solution of this salt and leave it for a few days. The piece will gradually increase in size by the addition of alum from solution, giving rise in time to a well formed crystal. Delicate crystals of ice of great beauty can sometimes be seen on window panes and elsewhere. The reader should look for examples of crystallization such as these.

Cleavage.—Certain crystals or fragments of minerals are found to break or split, with more or less smooth surfaces, in some directions more readily than in others. This character is known as cleavage. We have already seen that feldspar exhibits this phenomenon, while quartz does not (Fig. 3). Many minerals exhibit cleavage in a number of directions. The result of this is that characteristic forms are produced, *e.g.*, as in the case of feldspar. If a cleavage piece of this mineral be examined it will be seen that certain faces or planes are smoother than others. The cleavage is thus shown to be more perfect in certain directions than in others.

When cleavage is very imperfect or absent, the surface produced by the fracture of a mineral specimen is often characteristic. In certain cases the surface may resemble that of a piece of broken iron, when it is said to be "hackly." At other times the fracture is described by the use of certain common terms such as uneven or splintery. Quartz and other minerals may show what is known as a conchoidal or shell-like fracture.

Hardness.—One of the characters most commonly made use of in determinative mineralogy is that of hardness. Certain minerals are very soft. They may be easily scratched with the finger-nail or will produce, if they are not colorless, a line on a sheet of white paper if drawn gently across it. To this is due the use which is made of the mineral known in commerce as "black lead." Some minerals, on the other hand, are so hard that they cannot be cut or scratched by hardened steel. The high degree of hardness of some of these is the property which makes them useful in the arts. Common grindstones, which are composed essentially of quartz, and wheels of similar form made of the mineral emery, are employed in the grinding down or sharpening of iron and steel tools. The use of the diamond in cutting glass and in grinding and polishing other materials is well known. The hardness of an unknown mineral is usually determined by comparing it with that of well-known minerals. For this purpose ten minerals of varying degrees of hardness have been selected. Conventionally these are said to range in hardness from 1 degree, the softest, to 10 degrees, the hardest. Theoretically, however, the degrees are not all equal, that between one and two, for instance, being less than that between nine and ten. We shall refer to this scale of hardness again, after we have described the minerals which are used in the scale.

If a specimen of quartz be drawn with a slight pressure over a piece of ordinary glass, *e.g.*, window glass, it will be seen that the mineral leaves a mark on the glass which cannot be rubbed off. The quartz is said to scratch the glass and is thus found to be of superior hardness. Minerals of a considerably less degree of hardness may make a mark on the glass which disappears on rubbing with the finger or handkerchief. It is thus necessary to avoid confusion by distinguishing clearly between marking and scratching. Those minerals which are harder than quartz, 7, are few in number and include the highly-prized gem stones. A smooth face of a clear quartz crystal serves as an easy means of detecting these minerals. Such crystals cost a few cents apiece, and one of them should be carried while on a mineral-hunting expedition. Compare the hardness of feldspar, mica and calcite, which were mentioned in speaking of granite and limestone, with that of quartz. Try to scratch each of these minerals with a pocket knife.

Minerals possessing a hardness of 1 or 2 degrees are easily scratched by the finger-nail. The former possesses a soft, soapy or greasy feel in the hand. Those with a hardness of 3 cannot be scratched by the finger-nail, but are easily cut by the knife. Those with a hardness of 4 can be scratched by the knife, but are not easily cut.

A mineral whose hardness is 5 is somewhat difficult to scratch with a knife, while one whose hardness is 6 is scarcely scratched, if at all, by the knife.

It should be remembered that minerals are frequently mixed in nature. Hence in testing the hardness of a mineral comparatively low in the scale a scratch may be made on glass by minute grains of other minerals in the specimen.

On the other hand, it should not be forgotten that most minerals become altered or changed to other compounds in the course of time. The secondary minerals thus formed frequently possesses a lower degree of hardness than those from which they were derived. The hardness of a partly altered mineral is therefore deceiving at times. A distinction is to be made between the hardness of a mineral and the quality which practically all hard minerals possess of breaking or separating readily into fragments with a blow. Native gold and silver, which are low in the scale of hardness, can be flattened out with a blow from a hammer without breaking into fragments. They, and a few other minerals possessing this quality, are said to be malleable. Quartz and most minerals fly to pieces when so treated and are termed brittle. Gold and silver can be drawn out into wire or pressed into other forms and are said to be ductile. The terms sectile, flexible, and elastic will be referred to when describing certain mineral species.

Magnetism.—Two minerals, described on following pages, attract the magnet and are said to be magnetic. While magnetism may be detected by bringing an ordinary magnet, of the horse-shoe or bar form, almost in touch with a hand specimen or large fragment of a mineral, it is best to reduce a part of the specimen to a coarse powder. Then if the magnet is brought close to the grains they will rise and cling to it. Magnetic minerals at times occur in large masses. They then exert such an influence on a compass as to render it unfit for use in their vicinity.

A pocket knife with a magnetized blade is one of the most serviceable magnets, the knife being also useful for determining the hardness of minerals.

Lustre or Aspect. — In reference to this character minerals are divided broadly into two groups: (1) those with a metallic lustre, as that of steel, silver, copper, or other common metal; (2) those with a non-metallic lustre, such as that possessed by substances which are generally spoken of as stones. Certain substances possess a lustre intermediate between metallic and non-metallic, *e.g.*, that of hard coal, which is spoken of as sub-metallic. There are several varieties of non-metallic lustres, and such terms as earthy, stony, silky, resinous, vitreous or glassy, and adamantine are used to describe them. The application of some of these terms will be learned from the descriptions of minerals on following pages.

Minerals of a true metallic aspect are always opaque, even on a thin edge, while their powder is always black or distinctly colored.

Color. — There are few minerals among those with a metallic lustre which vary in color, no matter from what localities they are brought, or under what conditions they are found. This character becomes of great value in determining minerals which belong to this class. Steel, pure gold and copper, and other metals used in the arts, also possess a color which does not vary. It should be remembered, however, that the colors may change on the surface of some of these substances through tarnishing.

Minerals of a non-metallic aspect show great variability in color. Feldspar is commonly white, gray, or pink, and more rarely black or green. Quartz may be found of many colors.

Streak.—If an edge or corner of a mineral specimen is drawn across a piece of unglazed porcelain, a mark is usually left which shows the color of what is technically known as the "streak" of the mineral. The character is a valuable one on account of its uniformity. No matter how many colors a mineral may exhibit in different specimens, the streak will remain the same throughout. White, black, and green feldspar, for example, all possess a white streak.

A small three-cornered file is useful in determining the streak of moderately hard minerals. In trying the streak of very hard minerals it is necessary to crush a part of the specimen to fine powder, the color of which represents the streak; otherwise a greyish black streak, from the abrasion of the file, is likely to be left on the specimen. It is of course not necessary to try the streak of white or colorless minerals.

Fusibility.—This and other characters depending on heat are mentioned on another page in the description of minerals.

Transparency.—The terms transparent, translucent and certain optical terms will be made use of in describing individual minerals.

Taste and Odor.—A few minerals are more or less soluble in water and possess a characteristic taste. The terms used in describing this character, such as saline, the taste of common salt, are self-explanatory.

Certain minerals and rocks have a distinct odor under some conditions. Moistened clay and minerals of similar composition give off an argillaceous, or clayey, odor when breathed upon. A few varieties of limestone and other rocks and minerals, impure through the presence of some compound of sulphur, have a fetid odor, or odor of rotten eggs, if rubbed or struck sharply. If specimens or masses of certain arsenic-holding minerals are struck with a hammer a garlic odor rises. If certain sulphides are similarly treated a sulphurous odor is produced.

Specific Gravity.—If equal sized specimens of feldspar and iron or lead be examined in the hand it will be found that one is much heavier than the other. Lesser differences in weight are found among most minerals. This fact that equal volumes or bulks of different minerals are found to be different in weight, when examined in the hand or placed on a balance, is of importance. With a little practice it is often possible to distinguish, by the weight in the hand, two minerals which look much alike.

By the use of even a rough balance, such as an "apothecary's scale," it is easy to make finer distinctions between minerals than by the hand. If a fragment or crystal of a mineral be weighed, first in air and then in water, we obtain data with which we can make very delicate distinctions between minerals. A crystal of calcite, for instance, was found to weigh, when suspended in the air, 66 grains. When suspended in water the weight was 42 grains.

The loss of weight in the latter case equals the weight of the displaced water. The specific gravity of the mineral is determined by dividing the weight in air, by the difference between the weight in air and the weight in water.

$$\frac{66}{66-42} = \frac{66}{24} = 2.75.$$

The specimen is thus shown to be 2.75 times heavier than an equal volume of water. Its specific gravity is hence said to be 2.75.

An apothecary's balance can be easily adapted to specific gravity determinations. Shorten the strings on one of the pans and make a hole through the pan for the passage of a horse hair or silk thread, four or five inches in length. The free or lower end of the hair or thread is tied into a slip-knot for holding the specimen whose weight is sought.

Specific gravity is made use of in ascertaining the amount, in tons, of ore in heaps or in deposits of known dimensions. A specimen of ore, for instance, has a specific gravity of 5. A deposit of this ore is known to be 100 feet in length, 200 feet in depth and 10 feet in thickness. This represents $100 \times 200 \times 10 = 200{,}000$ cubic feet. Since the ore has a specific gravity of 5, and a cubic foot of water weighs 62.32 lbs., the ore known to be in the deposit weighs—

$$\frac{200{,}000 \times 5 \times 62.32}{2000} = 31{,}160 \text{ tons of } 2000 \text{ lbs.}$$

USE OF PHYSICAL CHARACTERS.

In order to test his knowledge of the physical characters of minerals, which have now been described, the reader should make use of the following table in the determination of any specimens of common minerals he may have at hand.

TABLE FOR THE DETERMINATION OF COMMON MINERALS BY FIELD TESTS.

[The numbers in brackets refer to pages in this book where the mineral is described.]

I—The Mineral has a Metallic Lustre.

A.—YELLOW COLOR.

1.—Only slightly scratched by knife; scratch glass.

Brass yellow; often in cubes; streak, grayish black	IRON PYRITES, PYRITE OR FOOL'S GOLD	(64)
Light yellow or yellowish white; weathers easily to rust which has inky taste	MARCASITE	(66)

2.—Easily scratched by knife.

Malleable	NATIVE GOLD	(60)
Magnetic; bronze yellow in color; surface often tarnished; streak, black; brittle	PYRRHOTITE OR MAGNETIC PYRITES.	(66)
Brass yellow with often a variegated tarnish; streak, dark green or greenish black; brittle	CHALCOPYRITE OR COPPER PYRITES.	(67)

B.—RED COLOR.

1.—Malleable.

Frequently tarnished green or blue	NATIVE COPPER	(63)

2.—Non-Malleable.

Perhaps slightly magnetic; streak, red; more or less earthy.	RED HEMATITE	(78)
Variegated purple tarnish, but reddish on fresh fracture; streak, grayish black	BORNITE	(68)
Pale copper-red; hard; heavy; brittle; streak, pale brownish-black	NICCOLITE	(69)

C.—GRAY COLOR.

1.—Scarcely scratched by knife.

Steel gray color; micaceous structure; streak, dull red	SPECULAR ORE OR HEMATITE	(78)

2.—Easily scratched by knife.

Dark lead-gray color; blue or green tarnish; streak, black; heavy	CHALCOCITE OR COPPER GLANCE.	(72)
Lead-gray color; cubic cleavage or granular; heavy; brittle	GALENA	(70)
Bluish light gray; often dark tarnish; good cleavage in places	STIBNITE	(71)

D.—WHITE COLOR.

1.—Scarcely scratched by knife.

Silver-white or pale gray; streak, grayish black; heavy; garlic odor when struck by hammer (*See also* SMALTITE, &c.)	ARSENOPYRITE OR MISPICKEL	(68)
White to pale yellow; exposed surface rusted	MARCASITE	(66)

2.—Easily scratched.

Malleable; often black tarnish and wire-like or leafy form	NATIVE SILVER	(61)

E.—BLACK COLOR.

1.—Scarcely scratched by knife.

Streak, black; magnetic	MAGNETITE	(79)
Streak, brown or blackish brown; scarcely a trace of magnetism	TITANIFEROUS IRON ORE	(80)
Streak, brown or greenish; scarcely a trace of magnetism; no cleavage	CHROME IRON ORE.	

2.—Easily scratched by knife.

Mostly in scales or compact; marks on paper; greasy feel	GRAPHITE	(55)
Like graphite, but with distinctly bluer color, and higher specific gravity; greenish streak	MOLYBDENITE	(56)
Black, or dark lead-gray; malleable; cuts like lead	ARGENTITE	(72)
Fibrous; soils fingers	PYROLUSITE	(84)

II—The Lustre of the Mineral is Sub-Metallic.

1.—Not scratched by knife.

Streak, brown ; color, brown or reddish ; heavy	CASSITERITE OR TINSTONE	(83)

2.—Scratched by knife.

Good cleavage ; streak, brown ; color, yellow, brown, or black	SPHALERITE OR ZINC BLENDE	(70)

III—The Mineral has a Non-Metallic Lustre.

A.—STREAK DISTINCTLY COLORED.

1.—Streak, brown or yellowish.

(*a*) Not scratched by knife	CASSITERITE	(83)
(*b*) Scratched by knife ; good cleavage	SPHALERITE	(70)

2.—Streak, yellow or brownish yellow.

Botryoidal surface, or earthy	LIMONITE OR BOG IRON	(80
3.—Streak, red	HEMATITE	(78
4.—Streak, pale green ; color, green	MALACHITE	(87)
5.—Streak, pale blue ; color, blue	AZURITE	(88)

B.—STREAK WHITE OR FAINTLY COLORED.

(*a*) *Not scratched by knife, or scratched with difficulty.*

1.—CLEAVAGE, NONE OR INDISTINCT.

Vitreous ; colorless, to amethystine and black	QUARTZ	(75)
Vitreous ; black, dark brown or green ; often in triangular prisms, striated and broken	TOURMALINE	(97
Dark red or brown ; generally in isolated rounded crystals (Figs. 52, 53)	GARNET	(96

2.—CLEAVAGE DISTINCT.

Vitreous or pearly ; white, grey, red, green, etc. ; very perfect cleavage (Fig. 3) ; fragments harder than those of calcite	FELDSPAR	(90)
Vitreous ; black, brown, green, greenish white or colorless	AMPHIBOLE AND PYROXENE	(93)

(*b*) *Scratched by knife.*

Yield no water in closed or open tube. (*See* WATER TEST, *p.* 206.)	1. White gray, etc.; soft; remarkable rhombohedral cleavage; effervesces in cold acid (*See* FELDSPAR *above*.)	CALCITE	(84)
	2. Same, but effervesces only in hot acid	DOLOMITE	(86)
	3. Mostly with good cleavage; very heavy; light colors; sometimes fibrous	BARITE OR HEAVY SPAR	(106)
	4. Same, but not quite so heavy; often fibrous structure	CELESTITE	(106)
	5. Harder; violet blue, green, grayish; frequently in cubes; octahedral cleavage	FLUOR SPAR	(74)
	6. Hard; often in six-sided prisms; green, reddish-brown, etc.	APATITE	(109)
	7. Soft; taste, strongly saline	ROCK SALT	(73)
Often in thin plates or scales. Yield water in the open or closed tube.	1. Very soft; scratched by nail; white or grayish; often satiny lustre	GYPSUM	(104)
	2. Sectile; soapy feel; green, brown, white, or mottled; perfect cleavage at times	TALC	(98)
	3. Like talc; massive or fibrous	SOAPSTONE AND SERPENTINE	(98)
	4. Dark or light green; earthy or scaly; scales not elastic	CHLORITE	(100)
	5. In elastic leaves or scales cleaving into thin plates	MICA	(88)
	White or brownish	MUSCOVITE.	
	Brown or black	BIOTITE.	
	Amber colored	PHLOGOPITE	

B.—DESCRIPTIONS OF MINERALS.

Of the seventy odd elements which have been discovered, eight make up approximately eighty per cent. of the crust, or that part of the earth which is accessible to man. These, in the order of their importance, are oxygen, silicon, aluminium, iron, calcium, magnesium, sodium and potassium. While many of the others are of great importance in commerce, they form a small percentage of the crust.

A table of the elements will be found on page 209.

The minerals important as constituents of rocks are few in number. The compounds represented by these minerals consist essentially of simple oxides, silicates and carbonates.

A number of elements are found in the crust in the uncombined or native state. Some of these, although occurring in comparatively small quantities, are of great importance to man.

It will be noticed that no definite system has been adopted in naming minerals. The names have been derived from certain characteristics of the minerals, or from localities in which they were first discovered, or have been given in honor of prominent workers in mineralogy, and so on.

Since many of the minerals here described can be identified without the use of chemical or blowpipe tests, the description of these tests is placed in an appendix (page 194). The beginner should try to identify minerals as far as possible by means of physical tests alone. A list of common minerals with which the reader should first become acquainted is given on page 110.

The classification used in the following descriptions is a chemical one. The minerals are dealt with in this order:

(1) Native Elements, together with some Compounds of Carbon; (2) Sulphides and Arsenides; (3) Chlorides and Fluorides; (4) Simple Oxides; (5) Carbonates; (6) Silicates; (7) Sulphates; (8) Phosphates.

I.—NATIVE ELEMENTS.

The elements which occur in the native or uncombined state in nature are not numerous. Most of them are, however, of great importance. Among these are the gas, oxygen, the minerals, graphite, diamond, native sulphur, and the native metals, gold, silver, platinum and copper. Iron, the metal of greatest industrial value, is rarely found, and then only in small quantities, in the native state.

Graphite and other Forms of Carbon.—The mineral graphite is popularly known as plumbago or black lead. Since it is composed of carbon it will be seen that the latter name is misleading.

Graphite is in common use in the arts. Its chief characteristics—softness and color—are known to every one. In addition to its use in pencils, it is employed in the manufacture of stove polish and for crucibles. Unlike coal, which also contains a high percentage of carbon, graphite is unaffected by the heat obtainable in ordinary furnaces. It is only slightly acted on by fluxes and has therefore been found well adapted for use in crucibles or vessels in which metals and ores are melted. Very pure, ground graphite possesses advantages over grease and oils for application to the running parts of certain machines, *e.g.*, the bicycle, and is thus classed as a lubricant. During recent years the mineral has been used as a base for paints. It is well adapted to this use as it is not acted on by the air or by acid or other fumes.

Graphite deposits are found in the older or crystalline rocks, frequently in crystalline limestone. At times it occurs in large, compact masses and again in flakes or scales. From the fact that the flakes frequently show a regular hexagonal outline, the mineral is referred to the hexagonal system.

On account of its lightness (sp. gr. 2.2), it is refined in the following way. The lumps or masses of the graphite associated with more or less mineral or rock matter, such as are obtained from the mine or quarry, are pulverized and thrown into water. The graphite is floated off, and the associated material, which is heavier, sinks. More complicated methods are, however, sometimes used.

The mineral which is most likely to be mistaken for graphite is molybdenite. The latter can, however, be recognized by its bluish-black color, its greenish instead of black streak, and from the fact that it is a sulphide.

Diamond, while possessing the same chemical composition as graphite, crystallizes in octahedrons and other forms of the isometric system instead of in the hexagonal system, and has other characteristics – lustre, hardness 10, specific gravity 3.5 —which cause it to be easily recognized.

MINERAL COAL is composed for the most part of carbon. Since however it contains different kinds of hydrocarbons, with perhaps in some cases free carbon, it cannot rightly be classed as a mineral. It is more properly a rock.

The variations in coal depend upon the amount and character of the volatile ingredients and on the structure, lustre and other physical characters. The color varies from black to brown, and occasionally iridescent. Coal is opaque and brittle.

No hard and fast lines can be drawn between the different varieties, one passing into another by insensible gradations. Those kinds which are most compact and contain the lowest percentage of volatile constituents have been subjected to the greatest amount of heat and pressure in the earth's crust.

Anthracite or hard coal contains from 85 to 95 per cent. of carbon. It burns with a feeble blue flame without smoke. Its lustre is bright, often sub-metallic, iron black, and at times iridescent. Its hardness is 2 to 2.5, and the specific gravity averages about 1.5. Becoming less hard and containing more volatile matter, it graduates into bituminous coal.

Bituminous coals, or what are in eastern North America usually called soft coal, consist of a number of kinds which differ in action under heat and are, therefore, of unlike constitution. They all burn with a yellow, smoky flame, and give out on distillation gas, oils or tar—hence the name bituminous. The ordinary varieties of bituminous coal contain a higher percentage of carbon than the so-called brown coals or lignites. The latter contain considerable water which evaporates on exposure to the air and causes the coal to break up or disintegrate. Lignite shows a more or less woody structure.

Peat is another substance which may be classed as a coal. It is made up of the partly altered remains of mosses and other vegetable matter mixed, usually, with a certain amount of sand or other non-combustible matter. To fit it for use as a fuel it is, on this continent, after being dried, subjected to pressure in a machine and reduced to briquettes or lumps of material, a few inches in diameter, which have a coal-like appearance.

Coke is the residue from the distillation of bituminous coals in retorts or ovens. The gaseous distillates are largely used for illuminating purposes. Coke is the fuel employed in blast furnaces and smelters.

Sulphur is present in most coals. It is usually in the form of the disulphide of iron, known as iron pyrites. It is the iron from this compound which gives rise to "clinkers" in coal stoves.

Coal is mainly of vegetable origin, which is shown by the abundant remains of plants found in many coal mines. It occurs in beds interstratified with shales, sandstones and other rocks.

There are a number of coal fields in both the United States and Canada. In the former country the chief anthracite field lies east of the Alleghany range, in a region in which the rocks have been much folded and disturbed, while bituminous coal is found farther west in a less disturbed region. The two varieties of coal are found under similar conditions in western Canada and elsewhere. This has led to the belief that pressure, and the heat induced thereby, have changed the soft coals, or those containing a higher percentage of volatile matter, into the harder kinds. The process has been simply a distillation by nature. The fact that peat, which is loose in texture and plainly composed of vegetable matter, can be changed by pressure into a compact coal has already been mentioned. In rare cases coal has been changed by natural agencies into graphite.

A few additional notes on the coal fields of North America will be given on another page.

Mineral Oil or Petroleum, since it is used largely as a fuel and for illuminating purposes, can be advantageously considered along with the coals.

Petroleum is a thick to thin fluid which is brown, yellow or colorless, and translucent to transparent. It consists of a mixture of compounds of carbon and hydrogen. It grades insensibly into solid bitumen. The lighter volatile compounds are separated by distillation and used for illuminating purposes, while the heavier oils and paraffins have a wide application in the arts. The thicker and denser varieties of petroleum are used as fuel.

Some of the best petroleum for the production of illuminating oils is found in Pennsylvania and the southwestern peninsula of Ontario. Fuel oils are found in California and other states.

Petroleum is found in stratified rocks of nearly all ages. In some localities it exudes at the surface. It is obtained by putting down drill holes a few inches in diameter through the strata. The oil has to be pumped from most of such wells.

Natural gas is found under about the same conditions as petroleum.

It has been generally believed that both petroleum and natural gas are formed by the distillation of organic remains entombed in rocks. During late years this theory of origin has been questioned by many workers who are inclined to believe that both materials are of inorganic origin. It is held that the materials originate in the heated interior of the earth and that they find their way gradually to or towards the surface through cracks and fissures.

Amber, which is a fossil resin or pitch, may be added to the list of carbonaceous materials.

Sulphur (S).—In addition to its occurrence in the mineral kingdom as a constituent of sulphides and sulphates, sulphur is at times found in large amounts in the free or native state. Volcanoes frequently give off sulphur in such large quantities as to form deposits of commercial importance. Decomposition of calcium sulphate, iron sulphide and other compounds also takes place beneath the surface of the earth in non-volcanic regions, and accumulations of sulphur result. Evolution of hydrogen sulphide and free sulphur from spring water is frequently seen.

Native sulphur is found in orthorhombic crystals, as well as in the form of powder, in masses. Its hardness is 1.5 to 2.5; specific gravity 2; lustre, resinous; color and streak, bright sulphur-yellow.

It is not necessary to dwell on the common uses and characteristics of sulphur, which are well known to every one.

Many of the compounds of sulphur, particularly sulphuric acid, are made from iron-pyrites, the disulphide of iron. When this mineral is roasted, fumes of sulphur dioxide are given off which are used in the production of the acid and for other purposes.

The closely related elements, antimony and bismuth, occur, like sulphur, in the native state as well as in compounds.

NATIVE METALS.

Gold (Au).—This metal occurs in few compounds in nature. In the native form it is found in grains, scales, and occasionally in lumps, known as nuggets, associated with gravel and sand. Such deposits of the metal are called placers. They are formed by the weathering or breaking down of gold-bearing rocks. The gold becomes more or less concentrated through the washing away of the lighter minerals by running water. Gold also frequently occurs in bodies of quartz which occupy fissures in compact rocks (Fig. 15). Its association with other minerals will be mentioned on following pages.

Gold is distinguished by its well-known yellow color, softness and malleability. The pure metal has a high specific gravity, 19. It is not affected by ordinary acids but is dissolved by aqua regia, which is a mixture of nitric and hydrochloric acids.

Native gold is usually alloyed with silver. The presence of this metal causes it to vary somewhat in color, that with much silver possessing a lighter color than that with a small percentage.

Minerals and deposits in which gold is found are described as being auriferous (gold-bearing).

Pure gold is called 24 carats fine. Alloys of the metal, consisting of 18 parts gold and 6 of some other metal or metals, are said to be 18 carats, and so on with other proportions. British sovereigns contain 91.67 per cent. of gold and 8.33 per cent. of copper. The gold coins of the United States and Germany contain 90 per cent. of the precious metal.

The most common method for extracting the metal from its ores is known as amalgamation. The fine particles, gold dust, which occur in placers or which are produced by the crushing of auriferous quartz, usually by means of stamps, or what may be called heavy pestles, in mills, are brought into contact with mercury. When the amalgam thus formed is subjected to heat, the mercury is volatilized and the gold is left behind. Chemical methods are, however, employed when the gold is intimately mixed with certain minerals such as iron-pyrites, the crushed auriferous material being subjected to the action of certain solutions. The two solution methods which are most commonly used are known as cyanidation and chlorination, from the names of the reagents. The gold after being dissolved is precipitated by suitable means. Gold is also extracted from certain of its ores by a process of smelting.

The two minerals which are most commonly mistaken for gold are iron-pyrites and scales of yellow mica. Pyrites can be distinguished by its hardness and brittleness. Mica when examined by the point of a knife blade is easily distinguished from the yellow metal. A speck or grain of gold in a rock or a piece of quartz has the same appearance in whatever direction it is viewed, while other minerals become brighter in some positions than in others. The speck of gold will flatten out under the pressure of the knife-blade.

An ounce of pure gold is always worth $20.66. The value of ores of gold or silver is stated in dollars or in Troy ounces for a ton of 2,000 lbs., or more, Avoirdupois.

Silver (Ag).—This metal, unlike gold, occurs in a number of compounds in nature. Native silver is found in the form of plates, leaves and wire-like structures in many localities. Its color, hardness and malleability serve to distinguish it. Galena and small glistening flakes of white mica are at times mistaken for silver. These minerals are, however, brittle and thus differ from the malleable metal. Silver tarnishes readily in the air. Its color must therefore be determined from a freshly-cut or broken surface. Galena and other minerals are frequently argentiferous (silver-bearing).

Silver, unlike gold, is soluble in nitric and other acids. It is extracted from its ores by processes similar to those used in working auriferous materials. Both native silver and gold fuse easily before the blowpipe to globules.

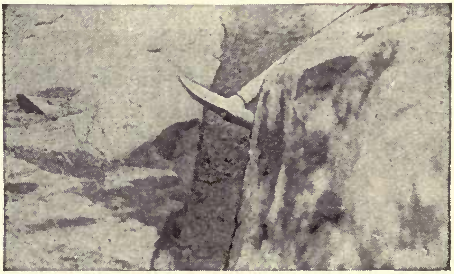

FIG 30.

A narrow, but very rich, vein containing native silver and other minerals at Cobalt, Ont. The head of the pick shows the width of the vein.

The price of silver is variable. At the present time it sells at about 60 cents an ounce, Troy.

Platinum (Pt).—This is a rare metal in nature, and at times, within the last few years, it has been more valuable than gold. Since it is in common use in the form of wire, it is well to be acquainted with its character and modes of occurrence. The metal is also used in the so-called platinum crucibles and dishes in the chemical laboratory owing to its not being acted on by common acids and fusing with great difficulty. It has other important uses.

Most of the platinum of commerce comes from placers, or deposits of sand and gravel, where it is found in grains and nuggets associated with gold and other heavy minerals. Only one naturally occurring compound of the metal, the diarsenide ($PtAs_2$), called sperrylite, is known. All the platinum produced from Sudbury, Ont., nickel-copper ores seems to occur in this form.

Platinum has a rather dull gray color. Its hardness is 4 to 4.5. The native metal has a specific gravity of from 14 to 19, according to purity.

Copper (Cu).—This metal, like silver, occurs both in the free state and in combination with other elements in nature. A few of its compounds are described on another page.

Copper and its compounds alter rather readily when exposed to the air, giving rise to carbonates, sulphates and other salts which possess characteristic blue or green colors.

Its malleability, together with its chemical and blowpipe reactions, serve to distinguish native copper. It fuses readily before the blowpipe into a shining globule, which becomes covered, on cooling, with a coating of black oxide. (See also borax bead test, Appendix I).

The three native metals, copper, silver and gold, crystallize in the isometric system.

While many uses are made of copper, the greater part of what is produced is employed in the form of wire and for electrical purposes.

Native copper is mined extensively in Michigan. Other great copper mining states are Montana and Arizona, where the metal is found combined with other elements.

Iron (Fe).—Metallic iron, unlike gold, silver and copper, is of rare occurrence in nature although the element is much more widespread in compounds than any of the three, being the substance to which the great majority of rocks and minerals owe their color. It is a curious fact, however, that metallic iron, in alloy with the closely related element, nickel, is a characteristic constituent of meteorites and forms the greater part of their masses.

The metallic iron of commerce is obtained chiefly by the reduction of the oxides of the metal, which are found in some parts of the world in large masses. These oxides, which have the formula Fe_2O_3 and Fe_3O_4, are known as hematite and magnetite, respectively (page 78).

II.—SULPHIDES AND ARSENIDES.

Mineral sulphides are numerous. With the exception of some varieties of zinc blende, those which are most frequently met with possess a metallic lustre by which they are distinguished from the sulphates. Some sulphides when roasted give off the odor of sulphur, while the sulphates do not. Many of the latter compounds, like artificial alum, are soluble in water, while the sulphides are insoluble.

SULPHIDES OF IRON.

There are two commonly occurring compounds of iron and sulphur which are represented by the formulas FeS_2 and Fe_7S_8.

Iron Pyrites (FeS_2).—This mineral is also known as pyrite. It is widely distributed in nature and is found associated with various rocks.

Pyrite frequently occurs in cubes. Octahedrons and pyritohedrons of the mineral are also common (Figs. 31, 32).

The mineral is at times found in large masses which are worked, as already stated, as a source of sulphur compounds.

The formula FeS_2 represents a percentage composition of sulphur 53.4, iron 46.6. The presence of sulphur with iron makes the mineral unsuitable as an ore of iron.

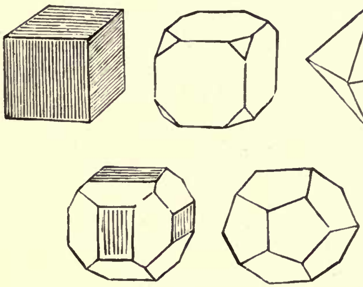

Fig. 31.—Crystals of Pyrite.

Upper line—cube, octahedron and combination of cube and octahedron.

Lower line—pyritohedron, or pentagonal dodecahedron, and combination of cube and pyritohedron.

The striations on the faces of the cube are characteristic of pyrite.

Pyrite is distinguished from other minerals, which are at times mistaken for it, by its hardness and color. It scratches glass, since its hardness is a little above 6, and has a light brass-yellow color together with a brilliant, metallic lustre. The streak is dark greenish black. Its color and that of copper pyrites, which is a deep brass-yellow, cause the two minerals to be known as "fool's gold." The hardness of copper pyrites is between 3 and 4, while gold is quite sectile. There is therefore no excuse for mistaking pyrite for either of these minerals. Some pyrite, however, carries sufficient gold mechanically

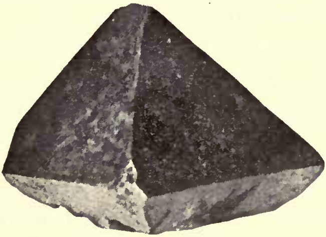

Fig. 32.
Octahedron of Iron Pyrites.
(One-half natural size.)

mixed with it to give it a value as an ore of this metal. Such associations are rare, most pyrite carrying no more than a mere trace of the precious metal.

The specific gravity of pyrite is 5. Since a cubic foot of water at ordinary temperature weighs approximately 62.32 lbs., how large a mass of pyrite will weigh a ton of 2,000 lbs.? A ton of pyrite, carrying 45 per cent. of sulphur, sells for about $5.00. What is the value of each one per cent. (or each unit as it is called in commerce) of sulphur at this price? The former question is asked in order to show the reader that a knowledge of the specific gravity of a mineral can be used in a commercial way, as well as being of service in the determination of an unknown mineral.

Heat a fragment of pyrite before the blowpipe or by other means, and note the character of the odor produced. If most of the sulphur is driven off the residue will be magnetic.

Marcasite possesses the same chemical composition as pyrite, but crystallizes in the orthorhombic system. The compound FeS_2, since it crystallizes in forms belonging to two systems, is said to be dimorphous. The color of marcasite is a paler yellow than that of pyrite, so that it is often called white iron-pyrites. As it is usually difficult to distinguish the one mineral from the other we shall not attempt in this elementary treatise to give a full description of marcasite.

Pyrrhotite (Fe_7S_8).—This mineral, like the oxide of iron known as magnetite, is distinguished by the fact that it is readily attracted by the magnet. Hence it is frequently called magnetic pyrites to distinguish it from the more commonly occurring pyrite.

Pyrrhotite possess a reddish-bronze color, a hardness of 3.5 to 4.5, and a specific gravity of 4.6. Its streak is greyish black. These characteristics enable one to distinguish it readily from pyrite.

Nickel is sometimes associated with pyrrhotite in sufficient amounts, as at Sudbury, Ont., to make the mineral valuable as an ore of this metal. At Rossland, B.C., deposits of pyrrhotite associated with copper pyrites are worked for the gold which they contain. The percentage of sulphur in pyrrhotite is so low that up to the present it has not been used as a source of this element, and in many localities the mineral, pyrrhotite, contains nothing of value.

SULPHIDES OF COPPER AND IRON.

The two most commonly occurring sulphides, in which copper is an essential constituent, are copper pyrites and bornite.

Copper Pyrites ($CuFeS_2$).—Another name for this mineral is chalcopyrite. It is the most widespread ore of copper. Its color and certain other characteristics have been given in the description of iron pyrites. Its streak is greenish black. The mineral occurs in the massive form much more commonly than in crystals. It is brittle and the cleavage is usually indistinct. The specific gravity is 4.1 to 4.3.

Copper pyrites is frequently tarnished, and, on decomposition, gives rise to characteristic blue and green carbonates and sulphates. The copper may be leached from the surface of a deposit of the mineral, which then has a yellowish or reddish, iron, color. The material in such an exposure is often called iron cap or gossan.

A fragment of the mineral dissolved in nitric acid imparts a blue color to the solution, which turns azure blue on the addition of ammonia in excess. Copper pyrites when heated before the blowpipe gives the odor of sulphur. The residue, which is magnetic, gives reactions for copper.

Since the mineral contains theoretically 34.5 per cent. of copper, it is a valuable ore of this metal when it occurs in large deposits such as are found in certain districts.

Bornite (Cu_3FeS_3).—This mineral is known under a variety of names, all of which refer to its striking purple or variegated color. Among these names are purple copper ore, peacock copper, and horse-flesh ore. On a fresh fracture it has a reddish bronze color and bright metallic lustre. The color changes, frequently within a few days, and the surface takes on a variegated or "peacock" appearance. Its hardness is 3 and specific gravity about 5. With nitric acid it gives the same reaction as copper pyrites. Crystals are not common.

Bornite contains theoretically 55.5 per cent. of copper and thus is, by weight, a more valuable ore than copper pyrites. The two minerals frequently occur together. Copper pyrites is, however, much more commonly met with, and is found in veins with pyrite and galena, and under many other conditions.

SULPH-ARSENIDE OF IRON.

Arsenical Pyrites (FeAsS).—Mispickel is a common name for this mineral. It is also known as arsenopyrite.

Fresh surfaces possess a silver-white color and metallic lustre. The color is duller on surfaces that have been exposed. The streak is greyish black. The mineral frequently occurs massive, but orthorhombic crystals are not uncommon (Fig. 33). Its hardness is 6 and specific gravity 6.

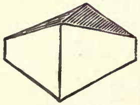

FIG. 33.
Mispickel crystal from Marmora, Ont.

Mispickel is the source of most of the arsenic used in the arts. The mineral when roasted gives off fumes of arsenic trioxide (As_2O_3). This compound is poisonous and is the "arsenic" or "white arsenic" of druggists. Arsenic is a constituent of Paris green and other substances used as insecticides. Variously colored compounds of the metal are employed as paints. There is a large consumption of white arsenic in the plate-glass industry.

Mispickel is frequently auriferous. Deposits carrying this variety of the mineral have been worked at Deloro and Temagami, Ont.

Iron, nickel and cobalt are the magnetic metals. It may be of interest to note that the latter two also occur as sulpharsenides in nature. These minerals are known as gersdorfitte ($NiAsS$), and cobaltite ($CoAsS$), and are comparatively rare.

The sulphides of arsenic, realgar (AsS) and orpiment (As_2S_3), are well known minerals. The former is red in color, and the latter is golden-yellow. They are both soft and sectile.

ARSENIDES.

Niccolite ($NiAs$) is one of the most important arsenides. On account of its pale copper-red color, this mineral is often called copper-nickel. It has a metallic lustre, a hardness of 5 to 5.5, and a specific gravity of 7.3 to 7.6. The composition is arsenic 56.1 per cent., and nickel 43.9.

Smaltite ($CoAs_2$) is a common ore of cobalt. It possesses a tin-white color like that of mispickel. Smaltite weathers to the beautiful rose-red arsenate of cobalt, known as cobalt bloom.

Both niccolite and smaltite, when roasted, give off arsenic trioxide, after the manner of mispickel.

The chief use of the metal nickel is in alloy with steel, which is employed for armour plate and other purposes. There are several minor uses of the metal, among which may be mentioned its use in coinage and in plating.

On account of its high price, cobalt is not used extensively in the metallic form in the arts. Owing to the beautiful blue color which it imparts to colorless silicates, when fused with them, its oxide is employed in staining glass and in coloring porcelain and pottery.

SULPHIDE OF LEAD.

Galena (PbS).—This is the common ore of lead. It possesses usually a brilliant metallic lustre, and a bluish lead-gray color and streak. The hardness is 2.5, and specific gravity 7.5.

The mineral crystallizes in the isometric system, commonly in cubes, and in coarse granular varieties. Cubic cleavage is very perfect (Figs. 34, 35).

The percentage composition is lead 86.6, sulphur 13.4.

Before the blowpipe on charcoal galena fuses, emitting a sulphurous odor, and is finally reduced to a globule of metallic lead. The charcoal is coated yellow (PbO) near the test substance, and white at a distance.

Galena frequently carries sufficient silver to cause it to be treated as an ore of this metal. The mineral is often found in association with limestones.

The uses of lead and its compounds are well known.

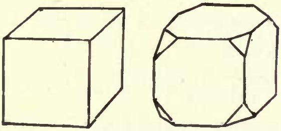

Fig. 34.
Crystals of galena.

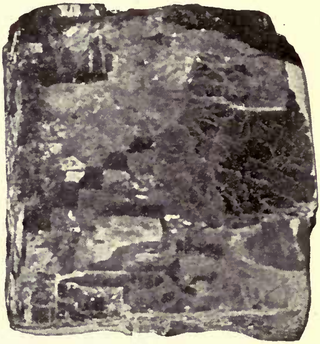

Fig. 35.
Cubic cleavage in galena.

SULPHIDE OF ZINC.

Zinc Blende (ZnS).—Sphalerite is another name for this mineral. Miners frequently call the darker varieties black-jack. The name sphalerite, which means deceiving, was given to it on account of the fact that it was mistaken for galena.

The mineral, which theoretically has the percentage composition, zinc 67, sulphur 33, usually contains some iron. The color is most frequently yellow or yellowish brown, at times black. Its lustre is usually resinous, differing from that of the other commonly occurring mineral sulphides. The streak is white, pale yellow or brownish. The mineral crystallizes in the regular system but good crystals are comparatively rare. The cleavage is distinct parallel to dodecahedral surfaces. The hardness is 3.5 to 4, and the specific gravity is about 4. Considerable practice is required in order to enable one to recognize the differently colored varieties of the mineral. By the use of the blowpipe, however, they are easily determined.

Zinc blende is frequently associated with galena. Grains, masses and veins of both minerals are commonly found in limestones.

SULPHIDE OF ANTIMONY.

Stibnite (Sb_2S_3) is the most important ore of antimony. It is found at times in beautiful prismatic crystals of the orthorhombic system.

The hardness of the mineral is 2; it is quite sectile and will mark paper, but not so easily as graphite. The color is bluish gray and the streak is nearly black. The lustre on a cleavage surface is metallic and brilliant.

The massive varieties of the mineral differ from galena in cleavage, and may be distinguised by the fact that when stibnite is roasted it gives off copious white fumes of oxide of antimony (Sb_2O_3). The specific gravity, which is 4.6, is much lower than that of galena.

OTHER SULPHIDES.

There are a number of mineral sulphides which are of rarer occurrence than those which have been described. Among these are the sulphide of copper, chalcocite, the sulphide of silver, argentite, the sulphide of mercury, cinnabar, and the sulphide of bismuth, bismuthinite.

Chalcocite (Cu_2S) is characterized by its blackish lead-gray color and streak, hardness 2.5 to 3, specific gravity 5.5 to 5.8. Specimens of the mineral are often tarnished blue or green. It resembles argentite but is more brittle.

Argentite (Ag_2S) is often found with native silver, and frequently occurs crystallized in octahedrons. The color and streak are blackish lead-gray. The hardness is 2 to 2.5, and specific gravity 7.3. The mineral cuts like lead, and has been mistaken for this metal from which it is, however, readily distinguished by its color.

Cinnabar (HgS) is the ore of mercury. It is a rare mineral, occurring in but few districts. It is somewhat sectile, hardness 2 to 2.5. The specific gravity is high, 8. The lustre is non-metallic or sub-metallic. The color is cochineal-red and streak scarlet, but these may vary somewhat through the admixture of clayey or other material. Some varieties might be mistaken for red hematite. Cinnabar is, however, readily recognized by its blowpipe reactions. On charcoal before the blowpipe the pure mineral is entirely volatilized. Heated in the closed tube with sodium carbonate, metallic mercury is obtained.

Bismuthinite (Bi_2S_3) is found in many mining districts. It is characterized by its lead-gray color and streak, and is usually foliated, massive or fibrous. The hardness is 2, the mineral being somewhat sectile. It fuses easily, and gives sulphurous fumes, and the yellow coating of bismuth oxide on charcoal. The yellow coating of bismuth can be distinguished from that of lead by the fact that all bismuth compounds, when fused on charcoal with a mixture of potassium iodide and sulphur, form a vivid scarlet coating on the support. If the reader has the reagents at hand, he should try this test for bismuth.

III.—CHLORIDES AND FLUORIDES.

There are only two commonly occurring minerals which come under this heading. These are rock salt and fluor spar.

Rock Salt ($NaCl$).—The other name for this mineral is halite. Its taste and the fact that it is readily soluble in water are known to every one, table salt being a purified form. It crystallizes in cubic crystals with cubic cleavage (Figs. 36, 37). Some of the purer varieties of table salt if examined with an ordinary magnifying glass will be found to be composed of minute cubical grains. Much of the salt used for domestic purposes contains some magnesium chloride which causes it to deliquesce or take up water when exposed to moisture.

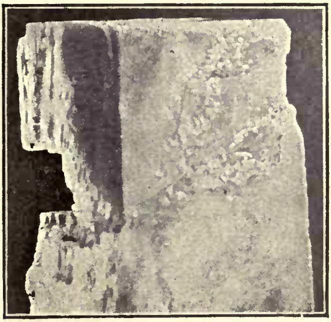

Fig. 36.
Rock Salt showing cubical cleavage.

Rock salt is colorless when pure but it also occurs in various shades of yellow, red and other colors. The hardness is 2.5 and the specific gravity 2.1.

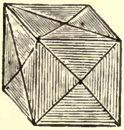

Fig. 37.
Crystal of Rock Salt. The crystals often have concave, or hopper-shaped, faces as this figure shows.

The mineral is found in solution in most natural waters. In some of these, as for example in the ocean, the Great Salt Lake of Utah and in other bodies of water, it occurs in considerable quantity. In some arid regions it is found in the solid state exposed at the surface of the earth.

In New York State, in the south-western peninsula of the province of Ontario, and in other districts, beds of rock salt lie at a considerable distance from the surface.

Much of the salt of commerce is derived from brine springs or salt wells, and from the waters of the ocean. The water is evaporated either by the heat of the sun or by artificial means. In some localities the mineral is obtained in the solid form by mining.

Fluor Spar (CaF_2).—This mineral is frequently found in good crystals, cubes, which possess a perfect octahedral cleavage (Figs. 38, 39). In color it varies from colorless to green, purple, yellow, and brown. The streak is white. The lustre is non-metallic; the specific gravity is 3.2, and the hardness 4.

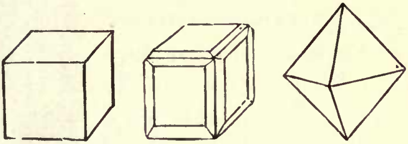

FIG. 38.—Fluor Spar Crystals.

Most examples, when moderately heated, exhibit a green or bluish phosphorescence; but if a fragment is heated rapidly, decrepitation almost invariably ensues. By fusion with the blowpipe a white enamel is produced. This tinges the flame red, and reacts alkaline after sufficient ignition. If fluor spar, in powder, is warmed with sulphuric acid, glass-corroding fumes are evolved.

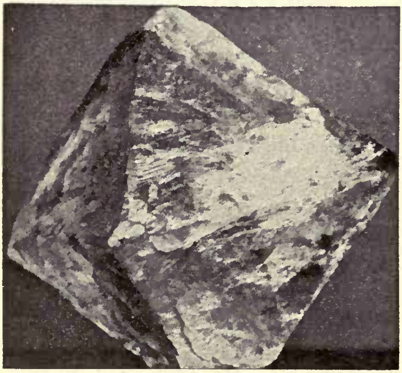

FIG. 39.
Octahedral Cleavage in Fluor Spar.

Fluor spar occurs commonly with ores of lead, silver, and zinc, in mineral veins. It is also frequently found in cavities and fissures in limestones and other stratified rocks. The chief uses of the mineral are as a flux and in the manufacture of hydrofluoric acid.

IV.—SIMPLE OXIDES.

The simple oxides, or those substances which consist of oxygen combined with only one other element, form an important and widely distributed group of minerals.

OXIDE OF SILICON.

Quartz (SiO_2).—This mineral is an essential constituent of two commonly occurring rocks, granite and sand or sandstone. It is also frequently found in the massive form, filling fissures in rocks, and is then known as vein quartz (Fig. 15).

Like most non-metallic minerals it is of different colors. The transparent, colorless varieties are known as rock crystal; the dark or smoky colored kinds are called smoky quartz or cairngorm. Amethyst is a purple variety which is used for ornaments. The white cloudy kinds are called milky-quartz. Rose-quartz is so named from its color.

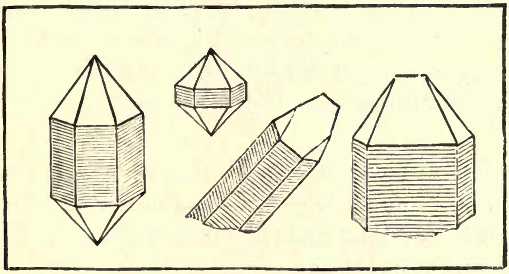

FIG. 40.—Crystals of Quartz.

Quartz possesses no cleavage, but breaks at times with a conchoidal fracture. This lack of cleavage, together with its glassy lustre, hardness, which is 7, infusibility, and the fact that is not acted on by ordinary acids, serve to distinguish quartz from other minerals with which it might be confused. The crystals, consisting of a hexagonal prism capped by a pyramid with six faces, also aid in its identification (Figs. 40, 41). The specific gravity is 2.6.

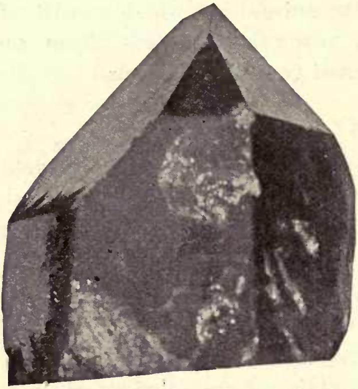

Fig. 41.
Crystal of Quartz.

There are a number of minerals closely related to quartz which are of considerable popular interest. They are composed of silica, but in the amorphous or imperfectly crystalline form. Among these are jasper, flint, hornstone, chert, chalcedony, agate and onyx.

Jasper is an opaque, impure quartz, typically red, but may be brown, green or otherwise colored.

Flint is duller in color and not quite so opaque as jasper. Its color is usually gray, brownish or nearly black. The flint Indian arrow-heads, specimens of which are to be seen in most neighborhoods, show that the mineral breaks with a conchoidal fracture and a sharp-cutting edge. Chert is a name given to impure flint.

Jasper is found associated with iron ores, especially in the states of Michigan and Minnesota, and in northern and northwestern Ontario. Flint and chert frequently occur in the form of concretions in limestones.

Chalcedony often has a stalactitic structure and its surface may present a botryoidal or other imitative form. The mineral may be either transparent or translucent. The lustre is waxy, and the color is usually white, gray or brown.

Cut and polished specimens of agate are commonly used for ornamental purposes. The mineral is a variegated chalcedony with bands of different colors arranged parallel, one to another. The bands are more or less curved (Fig. 42). Onyx is similar to agate in composition, but its parallel colored bands are straight, instead of being curved as in agate. The so-called onyx used as an ornamental stone in building is a variety of marble.

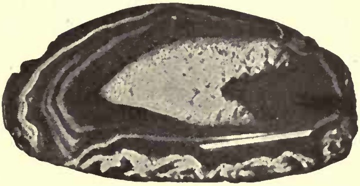

Fig. 42.
Polished Surface of Agate.

Agates are found in abundance along some parts of the shore of Lake Superior. Most of the polished specimens sold in this country come originally from South America. They are cut and polished in Germany.

There are a number of popular varieties of quartz and the other silica minerals just described which are given special names on account of differences in color, transparency and other characteristics. Among these are the so-called cat's eye, tiger-eye, moss-agate, carnelian, sardonyx, chrysoprase. Small rock crystals are so bright that they have often been called diamonds, *e.g.*, Lake Superior diamonds, although their hardness is much lower than that of true diamonds.

Opal is composed of silica, together with a small percentage of water. In being thus hydrated it differs from quartz and the other silica minerals just described. Several forms of opal are deposited by geysers and hot springs. These are known under the general name of sinter. The hydrous silica, which constitutes the frustules of diatoms and the skeletons of certain microscopic animals, is similar to opal. Tripolite or diatomaceous earth is commonly used as a polishing powder.

Opal occurs only in the massive form. Unlike the crystallized forms of silica, it is soluble in caustic alkalies. Both the hardness and specific gravity are slightly lower than those of quartz. The color is variable.

Opals frequently exhibit a beautiful play of colors. Among the most prized varieties is fire-opal, so-called from the red flashes of light shown by it.

Quartz is used for various purposes, in addition to those which have been mentioned. Spectacle-glasses are made from the clear flawless varieties of rock-crystal. Quartz-sand is employed loose and in the form of sand-paper for polishing. Sand or crushed quartz is also used in the manufacture of glass and porcelain. Quartzite and compact sandstone are employed as hearthstones. It may be added that quartz finds a use in certain smelting operations.

Oxides of Iron.

There are two important anhydrous oxides of iron and one hydrous oxide of the metal found in nature. These three oxides together with the carbonate, which is usually mixed with more or less earthy material and known as clay ironstone, constitute the ores of the metal.

Hematite (Fe_2O_3). — This mineral contains theoretically 70 per cent. of iron. It varies greatly in form and in appearance. At times it is compact and possesses a black or grayish black color and brilliant metallic lustre. Some varieties consist of scales similar in lustre and color to the more compact kinds. Much of the hematite worked as an ore is, however, loose and earthy in form and red in color. The name hematite, from the Greek word for blood, was given to the mineral on account of this color, and the fact that all varieties possess a dull-red streak. The bright metallic varieties are known as specular ore.

The hardness is 6 and the specific gravity 5.2. The loose varieties have a clayey or unctuous feel. The mineral crystallizes in the hexagonal system, but crystals, except microscopic forms, are not common.

Hematite becomes converted to magnetite when heated in small fragments in the reducing flame of the blowpipe on charcoal.

The largest iron ore mines in the world, those in the state of Minnesota, consist of hematite.

Magnetite (Fe_3O_4).—This mineral is frequently found in well formed octahedral and dodecahedral crystals (Fig. 43). Its hardness is 6 and the specific gravity 5.1. The lustre is metallic, usually brilliant. The color and streak are both black.

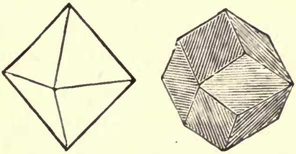

FIG. 43.
Magnetite Crystals.

The fact that the mineral is strongly magnetic, small fragments or grains being readily attracted by an ordinary magnet, serves to distinguish it from all other minerals with which it might otherwise be confused. It should also be noted that the streak of magnetite is quite different from that of the closely related mineral hematite.

The common occurrence of magnetite in sand along shore lines has been mentioned on another page. The mineral occurs in grains in many rocks, and on their decay, being little affected by weathering agencies, it becomes mixed with sand.

Although magnetite contains a higher percentage of iron, 72.4, than hematite, the latter is preferred as an ore by most furnace men. It is said to reduce more easily in the furnace than magnetite. Hematite has been found in much larger, purer, and more easily worked deposits than those in which magnetite occurs.

In order to be saleable, under ordinary conditions, ores of magnetite and hematite should contain not less than about

50 per cent. of metallic iron. Sulphur and phosphorus occur in some ores in sufficient amounts to make the ores either unmerchantable or so as to render them unfit for use in the manufacture of certain brands of iron and steel. Bessemer ores are those which are adapted for use in what is known as the acid Bessemer steel process. They should not contain more than about 0.05 per cent. of phosphorus. The rare element titanium is present in some magnetites in amounts which make the ores unsaleable.

Magnetite has been mined, in crystalline rocks, in several districts in eastern North America, notably near Port Henry, New York, and in south-eastern Ontario.

Limonite ($2\ Fe_2O_3$, $3\ H_2O$).—This ore of iron was so named on account of the fact that it is often found in marshy places (*leimon*, a swamp). A common name for it is "bog iron ore." It is frequently found near the surface of the ground, usually in lumps or small masses, more or less mixed with earthy materials. On account of the ease with which it is mined, it was the ore first used in many parts of North America. Most of the stoves and potash kettles of the early settlers were made of iron smelted from this ore. The ore usually contains a fairly high percentage of phosphorus. This makes a metal suitable for ordinary foundry castings. The percentage of iron in the ore is low compared with that in ordinary grades of hematite and magnetite.

Limonite is not known in the crystallized form. It frequently occurs in stalactitic shapes. The lustre varies from sub-metallic to earthy. It has a yellowish-brown streak and usually a brown color. Some varieties are known as brown hematite in commerce. Its hardness is 5 and specific gravity about 4. The mineral loses its water when heated, and ferric oxide is formed.

Brown ochre, an earthy form of limonite, and red ochre, a variety of hematite, are used for paint. Ochres of other shades are found. Their color depends on the character of the earthy materials intermixed with them and on the relative proportion of limonite and hematite in the mixture.

OXIDES OF OTHER METALS.

The other simple oxides which occur in nature are much less commonly met with than are those of iron. Since three of them are, however, frequently referred to in mineralogical literature, and are of much importance in the arts, we shall describe them briefly. Otherwise we should not have referred to them, as it is our desire to describe chiefly those minerals, specimens of which can be found by the reader in most localities.

Corundum (Al_2O_3).—This mineral is found as a constituent of certain metamorphic and igneous rocks, especially the syenites, and represents an excess of alumina in the molten masses from which these rocks crystallized just as the free or uncombined silica, quartz, in granite represents an excess of silica in the molten mass from which granite was derived.

Corundum is readily distinguished by its hardness, 9, and its comparatively high specific gravity, 4, from other non-metallic minerals, for which there is any likelihood of its being mistaken. It is infusible, unacted on by acids, and occurs in various colors. The common kinds are opaque and show rather perfect parting planes. The mineral crystallizes in the hexagonal system and is frequently found in elongated prismatic crystals capped by a pyramid (Fig. 44). Corundum, like many other hard minerals, is comparatively brittle.

The clear, transparent varieties of corundum are among the most highly-prized gem stones. The beautiful red and blue varieties, the ruby and sapphire, are the most valuable.

The mineral emery, which is in common use as an abrasive material, is a mixture of corundum with iron ore. The pure, opaque varieties of corundum are also extensively used for the same purpose and sell at a higher price than emery. Both minerals are crushed to the granular form, separated from foreign material, and sized. The materials are used in the granular form for polishing and grinding down surfaces, especially of metals. Grain emery and, at times, grain corundum are on sale in most hardware stores. Wheels, whet-

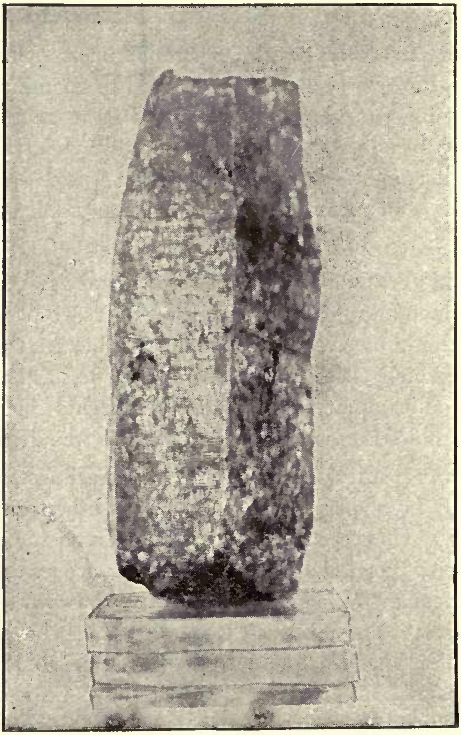

Fig. 44.

Corundum Crystal, without pyramidal planes. Craigmont, Renfrew County, Ont. (Crystal four inches long.)

stones, and other forms of abrasive instruments, are made by mixing grain emery or corundum with some cementing material and moulding the mixture into the desired shape. After being moulded, the articles, depending on the nature of the cement, are either allowed to harden or they are heated to a temperature sufficiently high to cause the cement to set. Wheels so made have, to a large extent, replaced grindstones cut out of sandstone, and they are replacing lathes in metal-working shops.

Most of the world's supply of corundum for abrasive purposes now comes from eastern Ontario. North Carolina was formerly the only producer in America. Both this state and Montana have produced the gem varieties.

Corundum is too high in price to be used as an ore of the metal aluminium. The mineral which is employed chiefly as the source of this metal is bauxite, which is a hydrated oxide of aluminium and resembles clay in appearance and in its mode of occurrence. Bauxite is mined in the southern States.

Cassiterite (SnO_2),—This oxide of tin, known also as tinstone, is the mineral which is worked as the ore of this important metal.

No deposits of cassiterite of much commercial importance are known in North America. Tin mines have long been worked in Cornwall, England. Most of the ore now comes from the East Indies.

The mineral occurs in well defined crystals of the tetragonal system, as well as in grains and irregular particles disseminated in granite (Figs. 25 *e* and 26 *d*). The variety known as stream-tin is found in rounded grains or pebbles in placer deposits. The mineral, when in crystals or pebbles, is rather easily recognised by its hardness, 6.5 to 7, and high specific gravity 7. The color is brown to nearly black, and the lustre adamantine.

Pyrolusite (MnO_2).—This oxide of manganese is an important mineral in the arts.

It is soft enough to soil the fingers. The color is greyish black. The streak is black and the lustre metallic. Crystals are not common, the mineral usually occurring in fibrous masses.

The presence of manganese in the mineral can be shown by simple blowpipe tests (page 205).

Pyrolusite deposits are found in New Brunswick and in Arkansas.

V.—CARBONATES.

The following naturally occurring carbonates are characterized by the fact that they effervesce when treated with hot acids. The hardness of none of them is above 4.

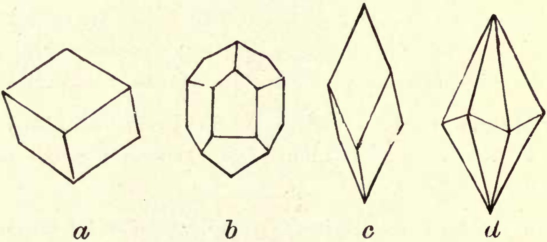

FIG. 45.

Crystals of Calcite.

Calcite ($CaCO_3$).—This is one of the commonest and most important of minerals. It, together with the closely related mineral dolomite, is the only essential constituent of the numerous varieties of limestone which form such a large part of the crust of the earth.

Calcite crystallizes in different forms of the hexagonal system, and the crystals possess very perfect cleavage (Fig. 45). The forms produced by cleavage are rhombohedrons. A variety known as dogtooth spar is so named on account of the shape of the crystals (Fig. 45, *d*). The clear varieties which are useful for optical purposes are known as Iceland spar. The best crystals are found in cavities or vugs in limestone and associated with various ores in fissures of other rocks. At times calcium carbonate is found in the fibrous form with a silky lustre, and is known as satin spar. Structures known as stalactites are frequently found hanging from the roofs of limestone caverns, and similar forms known as stalagmites project upward from the floors. They are formed by the deposition of calcium carbonate from solution in water charged with carbon dioxide gas, which drips from the roofs. Stalactites of small size are sometimes seen hanging from arches built of limestone.

The well known operation of producing quick lime from limestone depends on the fact that calcium carbonate when heated is decomposed into calcium oxide and carbon dioxide gas as shown by the equation:

$$CaCO_3 + \text{heat} = CaO + CO_2$$

Quick lime has an alkaline reaction, an avidity for water, and gradually takes up carbon dioxide, when exposed to the air, to re-form calcium carbonate.

Quick lime, when made into a thin paste with water and mixed with sand, about three and one-half parts to one of lime, forms common mortar.

Limestones containing a certain amount of argillaceous or clayey material produce, when burned, hydraulic, or, as they are called, natural rock cements. Such cements harden under water. Other uses of limestone are mentioned on a following page.

Calcite effervesces readily in cold dilute acid and is by this means distinguished from the closely related mineral dolomite, which effervesces only after the acid is heated.

Calcite is found of different colors. In the majority of cases it is, however, colorless. The lustre is usually vitreous, but in some earthy forms it is dull. Crystals possess a hardness of 3 and a specific gravity of 2.7.

Place a clear, transparent cleavage piece of calcite over a thin lead pencil line or dot on white paper, and turn the specimen slowly. In certain positions two images of the line or dot will be seen (Fig. 46). This character which crystals or cleavage pieces of calcite and other minerals, not of the isometric system, possess of showing two images when an object is viewed through the crystals in certain directions, is known as double refraction. It is not necessary for our purpose to give details concerning it.

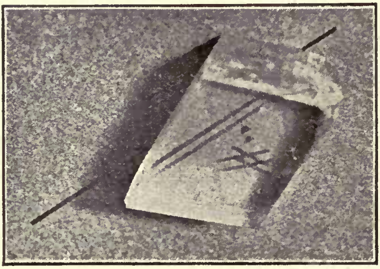

FIG. 46.

Double refraction in calcite rhombohedron. The calcite is photographed lying on piece of paper on which is a single line, a triangular dot and a cross. In looking through the calcite two images of the line, dot and cross, are seen.

Aragonite is calcium carbonate which crystallizes in the orthorhombic system. It is not so common a mineral as calcite.

Calcite is distinguished from quartz and feldspar, the minerals for which it is most commonly mistaken, by the fact that it is easily scratched by the knife. Quartz, moreover, possesses no cleavage.

Dolomite ($CaMg(CO_3)_2$).—The closely related metals calcium and magnesium, replace each other in compounds. Hence we find a gradation from pure calcite to dolomite. Limestones which hold magnesia in amounts from a few per cent. up to the percentage which makes them true dolomites are usually said to be dolomitic. The mineral magnesite contains, theoretically, no calcium oxide, its formula being $MgCO_3$.

Without the acid test, already mentioned, dolomite cannot be quickly distinguished from calcite. Its hardness is a little greater, 3.5 to 4 instead of 3, and its specific gravity is a little higher, 2.8 to 2.9. The angles of the cleavage rhombohedrons of the two minerals are also not quite the same (Fig. 45, *a*).

Siderite ($FeCO_3$).—At times more or less iron is found replacing the alkaline earth metals in dolomite. This denotes a passage from this mineral to the iron carbonate known as siderite or spathic iron, which is an important ore in some countries. It crystallizes in rhombohedrons, and has perfect rhombohedral cleavage. The color is light yellow to brown and lustre vitreous; hardness 3.5 to 4, specific gravity 3.8. It effervesces with warm acid and becomes black and magnetic before the blowpipe.

CARBONATES OF COPPER.

There are two carbonates of copper which are of economic importance and of fairly common occurrence. They are both hydrated carbonates. They fuse readily before the blowpipe, coloring the flame emerald-green, and on charcoal they are rapidly reduced to metallic copper. In acids they are soluble with effervescence. (See also Appendix I., Borax bead.) One of them, known as malachite, is a bright green mineral which is often found with other copper ores. It is rarely found in crystals. Common forms have a rounded or mammillary surface, and a radiating fibrous structure. The hardness is 3.5 to 4, and the specific gravity about 4. It contains, when pure, 71.9 per cent. of cupric oxide, CuO. The mineral at times occurs in masses of sufficient size to be cut and polished for ornamental purposes, such as vases and so forth.

The azure-blue carbonate is known as azurite. It is found crystallized. Its hardness and specific gravity are about the same as those of malachite. The mineral contains 69.2 per cent. of cupric oxide.

Copper sulphate, which is similar in color to azurite, is a frequent decomposition product of the sulphide ores of copper. Its solubility in water distinguishes it.

The carbonates of copper which, in some localities, occur in large deposits and constitute important ores, have in most cases been formed from the sulphides of copper by surface waters containing oxygen and carbon dioxide, so that when followed deep enough below the surface they are usually found to give place to the copper sulphide minerals.

VI.—SILICATES.

The naturally occurring silicates form a large group, some members of which are important both as rock-forming minerals and in the arts.

Many of these silicates have complex chemical formulas which we shall not give in the following brief descriptions.

The varieties of some silicates such as the feldspars, amphiboles and others are difficult to distinguish from one another without refined methods of examination. Hence we shall attempt to give little more than the leading characteristics of each class. All the members of the group have a non-metallic lustre. Their color, hardness and specific gravity are variable.

The Micas.—The micas are essentially silicates of alumina and the alkalies or alkaline earths. The chief characteristic of the more common varieties of this group of minerals is known to almost every one. It is known that mica splits readily into thin sheets, which are more or less transparent, flexible and elastic (Figs. 3, 47). They are minerals which, when in sheets an inch or two in size, cannot be mistaken for any other mineral.

The three chief micas are muscovite, so called because first used in Muscovy, biotite and phlogopite.

Muscovite is usually colorless and transparent, although at times it may be of a delicate pink or other color. It is the mica which is used in stove fronts. The mineral is a silicate of alumina and potash. All micas contain a small percentage of water.

Biotite and phlogopite are silicates of alumina, magnesia and iron. The former is commonly known as black mica. It is found at times in other colors. Phlogopite is extensively used as an insulating material in electrical machines, being better adapted for this purpose than the harder muscovite, white mica. Biotite usually contains too much iron to be used for this purpose. On account of its color phlogopite is known in commerce as amber mica. It is mined in eastern Ontario and in the adjoining part of the province of Quebec.

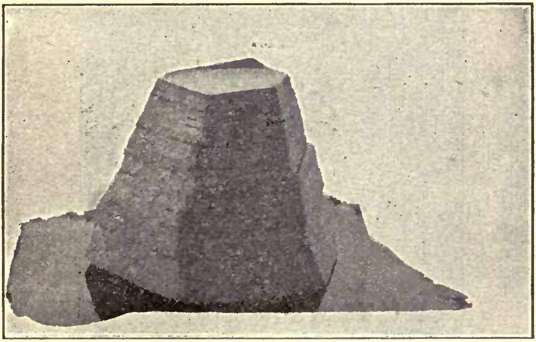

Fig. 47.

Crystal of Mica (phlogopite) showing cleavage parallel to the basal plane. The crystal photographed came from the vicinity of Sydenham, Frontenac County, Ont., and had a diameter of about one foot. [Mr. E. T. Corkill.]

The hardness of the three micas referred to lies between 2 and 3, and the specific gravity is from 2.7 to a little over 3.

All the micas occasionally occur in well defined crystals (Fig. 47). The cleavage is parallel to the base.

The muscovite of commerce is obtained chiefly from coarse granite dikes in New Hampshire, North Carolina, and other States, and from British India. Phlogopite occurs in much larger masses than muscovite and is associated with more basic minerals, such as pyroxene and calcite.

The Feldspars.—Like mica, feldspar is the name of a family of minerals. As rock constituents they are the most important of all minerals. The name – German for "field spar" —implies that they are of common occurrence. We have already seen that feldspar is a constituent of one of the most widely known rocks, granite. According to their crystallization, feldspars are divided into two groups: (1) Orthoclase and its clear transparent variety, sanidine, which belong to the monoclinic system, and (2) the plagioclases, which crystallize in the triclinic system (Figs. 48, 49, 1, 26 *c*). Refined methods of examination, which it is not necessary for our purpose to describe, are sometimes needed to distinguish the members of one group from those of the other, and more especially to identify the varieties which are to be found among the plagioclases. The beginner in the study need not greatly concern

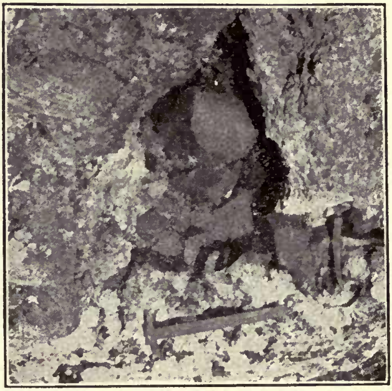

FIG. 48.

Crystals of feldspar in cavity in gneiss, Renfrew County, Ont.
[DR. A. E. BARLOW, G.S.C.]

himself with delicate distinctions. If he is able to recognise at all times any of the members of the family as a feldspar, he should be content to leave the recognition of finer distinctions to the future. There are a few characteristics, however, which will assist him in making broad distinctions among the varieties.

The feldspars are silicates of alumina with potash, soda or lime. Orthoclase and sanidine, or the monoclinic varieties, are the potash feldspars. Among the plagioclases there are albite, so named from its characteristic white color, and anorthite which contain only one element of the alkalies or alkaline earths. Albite contains soda in place of the potash of orthoclase, and anorthite has lime. Intermediate between albite and anorthite, which may be considered to stand, chemically, at the ends of the plagioclase series, are several varieties. Among these are oligoclase and labradorite. These contain both lime and soda, and may be considered to be composed of, what may be called, both albite and anorthite molecules. The following table, which the learner need not get by rote, shows the chemical relationships which exist among the feldspars mentioned.

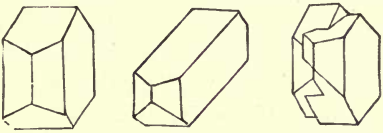

FIG. 49.—Crystals of Orthoclase. A twin crystal is shown on the right.

	Silica.	Alumina.	Potassa.	Soda.	Lime.	Total.
Orthoclase......	65	18	17	..	..	100
Albite..........	68	20	..	12	..	100
Oligoclase......	62	24	..	9	5	100
Labradorite.....	53	30	..	4	13	100
Anorthite.......	43	37	..	..	20	100

Oligoclase, since it contains a higher percentage of soda than of lime, may be called a soda-lime feldspar, and in distinction from it, labradorite is the lime-soda variety.

All feldspars possess easy cleavage in two directions at right angles, or nearly so, to each other (Fig. 3). If the cleavage faces are examined it will be found that the cleavage is more perfect in one direction than in the other.

Orthoclase has a hardness of 6, and is therefore hard enough to scratch glass, although distinctly softer than quartz. The hardness of the other members of the family ranges from 5 to 7. The lustre varies from vitreous to pearly. The color is usually light, and may be white, gray, red, brown or green. Pink or reddish is the characteristic color of orthoclase. The streak of the feldspars is always white.

Those feldspars which contain the highest percentages of silica are said to be the most acid. It is found, as would be expected, that the acidic varieties are characteristic of acid rocks, such as granite and other light colored kinds, while the more basic feldspars, or those containing less silica, are found in basic rocks, which are usually dark colored and comparatively heavy. We have thus a means, knowing their associations, of distinguishing orthoclase and the more acid plagioclases, albite and oligoclase, from the more basic feldspars.

Series of fine parallel lines or ridges are usually to be found on faces of the plagioclases, and are absent on orthoclase.

By exposure to the weather feldspars gradually lose their potash, soda and lime, and part of their silica, and are changed to kaolinite, which is the base of all clays.

In granite, as has been previously stated, grains of feldspar can be distinguished from quartz by the fact that they possess smooth, more or less bright, cleavage faces, while quartz breaks with an irregular fracture.

The cleavage forms of calcite and dolomite resemble those of feldspar, but they are easily scratched by the knife, while feldspar will scratch glass. The carbonate minerals will also, of course, effervesce in acids, while feldspar is not affected in like manner. Fine splinters of orthoclase, when held in the blowpipe flame, become rounded only on the edges. The more basic feldspars fuse more easily. In the arts feldspar is used chiefly in pottery. Since orthoclase is found in larger and purer masses than the other varieties, it is the one usually employed. The deposits of the mineral worked form parts of coarse-grained granite. The feldspar and quartz in deposits of economic value occur segregated or gathered together in masses, each pretty much by itself. These granites contain few minerals other than the two mentioned.

Amphibole and Pyroxene.—There are several varieties of amphibole and pyroxene, to each of which special names are given. Some of the members of each group of varieties are important as constituents of rocks. They are, however, not of such frequent occurrence as the feldspars, and are, especially when in grains in rocks, usually somewhat difficult for the beginner to recognize. The members of each group which are found in the more commonly occurring rocks are few in number and are distinguished by a black or dark color. The amphiboles are characteristic of the lighter colored or more acid igneous rocks, while the pyroxenes are frequently present in the darker, heavier and more basic varieties. The variety of amphibole, known as *hornblende*, is found, for example, playing the part of mica in certain granites and syenites. The commonest variety of pyroxene, known as *augite*, on the other hand, is only occasionally present as an essential constituent in the syenites, and is very rarely found associated with quartz as a rock-forming mineral.

From what has been said, the learner will understand that if he finds grains of a dark mineral in granite which do not possess the characteristic cleavage of mica, they are likely to be hornblende. If he observes a dark colored mineral in a heavy, basic rock, it may be a pyroxene, but since hornblende at times occurs in such rocks he may not be able to decide absolutely as to which of the minerals it is. For the present he should not be discouraged if he is able only to assure himself that the mineral is either hornblende or a pyroxene. Crystals and larger cleavage fragments of the two minerals are more easily distinguished, the one from the other.

Both hornblende and augite crystallize in the monoclinic system. Hornblende is frequently found in crystals with six prismatic faces, while in augite the number is commonly eight (Figs. 50, 51, 25 *b*). Alternate pairs of faces may be very small or absent in augite crystals.

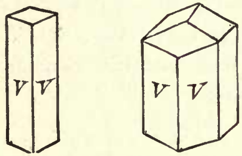

FIG. 50.
Monoclinic crystals of Amphibole. The angle V on V is 124° 30′. This is also the cleavage angle.

There is perfect cleavage in hornblende crystals parallel to some of the prismatic faces. The forms produced by this cleavage show angles of about 124°. The characteristic cleavage angle of augite is more nearly rectangular, being about 87°. Crystals of augite frequently show a tendency to separate into layers parallel to the basal plane,

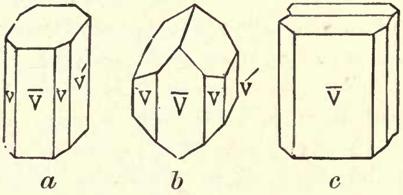

FIG. 51.

Monoclinic crystals of Pyroxene. The prism faces V, V meet (over $\overline{V}$) at an angle of 87° 5′; V inclines to $\overline{V}$ at an angle of 133° 33′; $\overline{V}$ and V′ form a right angle. *a* is the combination frequently presented by the light or dark colored varieties in crystalline limestone.. *b* represents the ordinary augite crystals of basaltic rocks. *c* represents a twin or compound crystal. [After CHAPMAN.]

which is inclined to the prismatic faces. The lines showing this structure can often be seen on faces of the prism. Slender, bladed crystals are more common with hornblende than with augite.

The lustre of both hornblende and augite is vitreous. Their color is black or greenish black, and the hardness 5 to 6. The specific gravity of hornblende is 2.9 to 3.4. That of augite is slightly higher, 3.2 to 3.5.

In composition the amphiboles and pyroxenes are somewhat complex silicates. The general formula for the two groups is $RSiO_3$, in which R stands for calcium, magnesium, iron and manganese. Some varieties in each group contain alumina in addition to the constituents mentioned.

The amphiboles are found more frequently in fibrous, acicular and bladed forms than the pyroxenes. True asbestos, or "mineral wool," is a fibrous variety of amphibole. The asbestos of commerce, of which by far the greater part of the world's supply is mined in the province of Quebec, is similar in form but different in composition, being a variety of the hydrated silicate of magnesia known as serpentine. Mountain leather is another curious variety of amphibole. Tremolite is a white or very pale green, fibrous amphibole found in crystalline limestone. Actinolite is green, commonly fibrous or columnar, and frequently shows a radiated structure. Certain amphiboles and pyroxenes are found crystallizing in systems other than the monoclinic. Enstatite and hypersthene are orthorhombic pyroxenes which are frequently found in basic rocks. Diallage is a pyroxene that is common in the basic rock known as gabbro.

Members of both groups of minerals are of little importance in the arts. Actinolite is mined in eastern Ontario, ground to powder and mixed with cement substances for use as a roofing material. Buildings in several cities of the United States are roofed with this mixture.

Olivine or Chrysolite.—This mineral, which is a silicate of magnesium and iron, is of comparatively rare occurrence. It contains only 41 per cent of silica and occurs as a constituent of certain basic rocks and in some meteorites.

Olivine is bright yellowish-green in color, and is usually found in the form of small grains. The lustre is vitreous. Its hardness is high, 6.5 to 7. The specific gravity ranges from 3.3 to 3.6.

Since the mineral weathers rapidly to serpentine, and is, moreover, of comparatively rare occurrence, specimens containing it are difficult to obtain in most localities.

Garnet.—There are several silicates, isomorphous in composition, to which the name garnet is applied. One of the most common kinds is a silicate of alumina and ferrous oxide. In the other sub-species, the iron is replaced by calcium, magnesium, or some other element whose oxide plays a similar part in compounds. The alumina may be replaced by ferric oxide or a chemically equivalent oxide.

Garnet is characterized by the fact that it usually occurs in distinct, well defined crystals, which are readily recognized. The crystals are most commonly rhombic dodecahedrons or trapezohedrons (Figs. 52, 53). Masses of the mineral are also found.

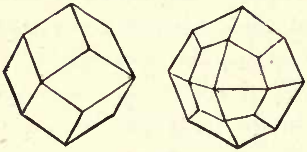

FIG. 52.
Garnet crystals.

The lustre is vitreous, and the color is most commonly pink or red, but may be green, brown, or of some other hue. The hardness is 7 to 7.5. The specific gravity is also comparatively high, 3.2 to 4.3.

Some of the most beautiful crystals of garnet are found in mica schist, and the mineral is also a constituent of gneiss and other rocks. Its occurrence with grains of magnetite, intermixed with sand on shores, has already been mentioned.

The common kinds of garnet fuse easily.

The clear, well-colored varieties are used as gems, *e.g.*, carbuncles. Garnet in the granular form is employed as an abrasive material, but is inferior for this purpose to emery and corundum.

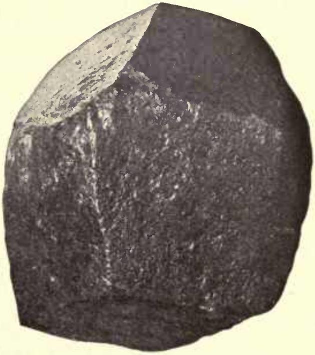

FIG. 53.
Large crystal (rhombic dodecahedron) of garnet. (About one-half natural size.)

Tourmaline.—This mineral frequently occurs in three-, six-, or nine-sided prisms, which render its recognition easy (Fig. 54). The common kind is black in color, and is sometimes mistaken for hornblende, from which it can be distinguished by its lack of cleavage. The prism faces show longitudinal striations. The black, massive variety, known as schorl, has frequently been mistaken for coal. It is, however, much harder, and, of course, will not burn. Schorl fuses easily.

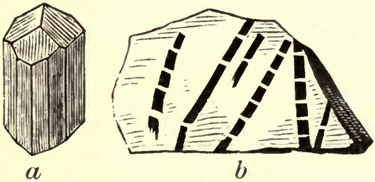

FIG. 54.
a, Tourmaline crystal; *b*, broken crystals in quartz.

Tourmaline is frequently found coating the faces of narrow fissures or cracks in granite as well as in the mass of this rock. Good crystals occur in crystalline limestone.

In composition the mineral is a complex silicate, which is of interest since it contains the element boron. The composition is variable and the mineral is found in various colors, black and brown being the most common.

The hardness is 7 to 7.5, and the specific gravity 3 to 3.2.

Frequently the crystals are black needles which occur in clustered and radiating groups.

Clear varieties, of a green or other color, are used as gems.

Topaz.—Although this is a rare mineral it is important, since it is used in the scale of hardness (page 110).

Topaz is a silicate of alumina which contains 17 per cent. of the element fluorine. It frequently occurs in beautiful clear crystals, which are prismatic in form and belong to the orthorhombic system. The basal cleavage is perfect. The lustre is vitreous and brilliant. Certain white massive kinds resemble quartz.

The color varies from colorless to white and wine-yellow. Other colors are sometimes seen.

The hardness is 8, and the specific gravity about 3.5. It is infusible.

The mineral is usually found in gneiss and granite associated with mica, tourmaline, fluorite, apatite, and at times with tin-stone.

The clear, well colored varieties are used as gems.

Serpentine, Talc, Chlorite, and Kaolinite. — These silicates are all secondary minerals, being formed by the alteration or decomposition of other minerals. They are common as rock constituents, and in this condition are often difficult to distinguish one from another.

Serpentine and talc are closely related minerals, both being hydrated silicates of magnesia. The former contains about 13 per cent. of water, and the latter approximately 5.

Talc is characterized by its softness, being easily scratched by the nail and has a soapy feel. It occurs both in the massive and foliated forms. In the latter case the leaves produced by the perfect cleavage are inelastic, thus differing from those of mica. The color is commonly white or sea-green. The specific gravity is 2.8. The compact, usually greenish-grey varieties are known as steatite or soapstone. The mineral occurs commonly in association with crystalline limestone.

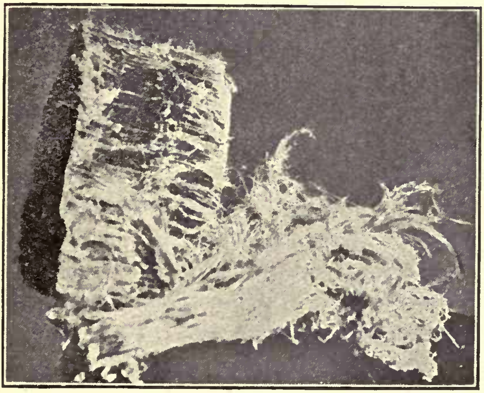

FIG. 55.
Asbestos (serpentine), Thetford Mines, Que.

Talc is ground and used as a filler in the manufacture of paper and for other purposes. Steatite is sawn into slabs for use in the construction of hearths and furnaces.

Serpentine has a hardness of 2.5 to 3. The specific gravity is 2.5. The lustre is greasy, wax-like or earthy. The color is usually green, but may be red or yellow.

Chrysotile is a fibrous variety of serpentine known in commerce as asbestos. The fibres are flexible and may be woven like wool or silk (Fig. 55). Fire-proof articles such as theatre drop-curtains, firemen's clothing, and mail bags are made of it. The world's supply of asbestos comes chiefly from the province of Quebec. In books on mineralogy the name is usually spelled asbestus.

Serpentine, as already stated, is an alteration product of olivine as well as of other basic minerals.

Meerschaum is a soft, white mineral which is light in weight, and is used for the bowls of tobacco-pipes. Like talc and serpentine, it is a hydrated silicate of magnesia.

Chlorite.—This is properly the name of a group, whose members are essentially basic, hydrous silicates of aluminium, magnesium, and iron.

Chlorites are found in various crystal systems, but all exhibit a perfect basal cleavage, and, like the micas, occur in plates or minute scales with a hexagonal outline. The plates break when bent and thus lack the elasticity of mica. In color they are usually green, but their structure serves to distinguish them from serpentine, with which they are sometimes confused. The hardness of the most common kinds is 2 to 2.5, and the specific gravity 2.65 to 2.78. The lustre is pearly to vitreous.

They are frequently alteration products of biotite, hornblende and augite.

The chlorites are of no economic importance.

Kaolinite.—This secondary mineral is important, owing to the fact that it forms the base of all clays.

Kaolinite is a hydrous silicate of alumina. The color is white. In form it is earthy and clay-like. The hardness is 1 to 2.5, and specific gravity 2.4 to 2.65.

It is the most common of all the hydrous silicates, and is a decomposition product of various aluminous silicate minerals, especially the feldspars. Under the action of carbon dioxide and water the feldspars give up their alkalies and alkaline earths and take up water, the resulting compound being kaolinite. Its argillaceous odor is characteristic.

Ordinary clays contain various impurities, such as oxides of iron, calcium carbonate, sulphates, and grains of various minerals and rocks. Kaolin is a clay which is comparatively free from such impurities.

The uses of clays in the manufacture of ordinary and fire brick, tile and other articles are well known. Very impure kinds are often used in the production of ordinary brick. Those used for fire brick approach kaolinite in composition.

Epidote is another secondary silicate, commonly green in color, which is of frequent occurrence in granite, gneiss and other rocks. Its association and color tend to cause it to be mistaken, at times, for serpentine or chlorite, but its hardness, 6 to 7, is characteristic.

RARER SILICATES.

The mineral silicates, known as zircon, scapolite, sphene, beryl, nepheline and sodalite, occur more rarely in most parts of the world than those which have been described. Since, however, specimens of these minerals are found in many collections it will be well to give a brief description of them.

Zircon usually occurs in well-formed crystals, of the tetragonal system (Fig. 56). Its color is brown, red, or reddish-yellow, with resino-vitreous aspect. The hardness is 7.5, and specific gravity 4. It is quite infusible before the blowpipe, and is not attacked by acids. The mineral is a silicate of the rare element zirconium.

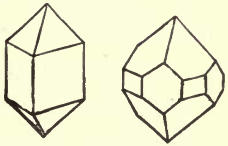

FIG. 56.
Crystals of Zircon.

Crystals of good size are found more commonly in syenite than in other igneous rocks. In eastern Ontario fine crystals frequently occur with pyroxene, apatite, and other minerals in crystalline limestone. The best crystals come from Sebastopol township, Renfrew county.

Scapolite also crystallizes in the tetragonal system in combinations, usually of a square-based prism and pyramid. At times the texture is more or less lamellar. The hardness is 5.5 to 6, and specific gravity 2.6 to 2.8. Before the blowpipe it fuses, mostly with strong bubbling. The mineral might be mistaken at times for feldspar or a light-colored pyroxene, but its crystal form distinguishes it. The best crystals of scapolite in the collections of the world, like those of zircon, probably come from eastern Ontario. These scapolite crystals, at times, have a diameter of six or eight inches. The mineral is, in some cases, an alteration product of basic feldspar, and is found in various rocks. The best crystals are associated with pyroxene, apatite, mica, calcite, zircon, and other minerals in deposits in crystalline limestone. Typically, the mineral is a silicate of soda, lime and alumina.

Sphene or titanite frequently occurs in fine crystals in deposits with scapolite, apatite, and other minerals in the crystalline limestones of eastern Ontario. In less perfect crystals, it is found in gneiss and other metamorphic rocks. In very small crystals it also occurs in igneous rocks. The crystallization is monoclinic. The color is usually brown, black or yellowish. The hardness is 5.6, and specific gravity 3.4 to 3.6. Before the blowpipe it melts, with bubbling, into a dark glass or enamel, but sometimes on the edges only. Typically, it is a silicate of titanium and lime.

Beryl is of importance owing to the fact that it is found in many coarse granite dikes associated with fluor spar, tourmaline, tinstone and other minerals. It usually occurs in long, prismatic, well formed crystals of the hexagonal system

(Fig. 57). The characteristic color is green, which causes beryl to be at times mistaken for apatite. Since the hardness of the latter is 5 while that of beryl is 7.5 to 8, the two can be readily distinguished. It will also be seen from what has been said in describing the modes of occurrence of the two minerals that one is not likely to be mistaken for the other in the field. Cleavage is indistinct in beryl. The mineral fuses with difficulty and is not acted on by acids. The clear emerald-green varieties are highly prized as the gem, known as emerald.

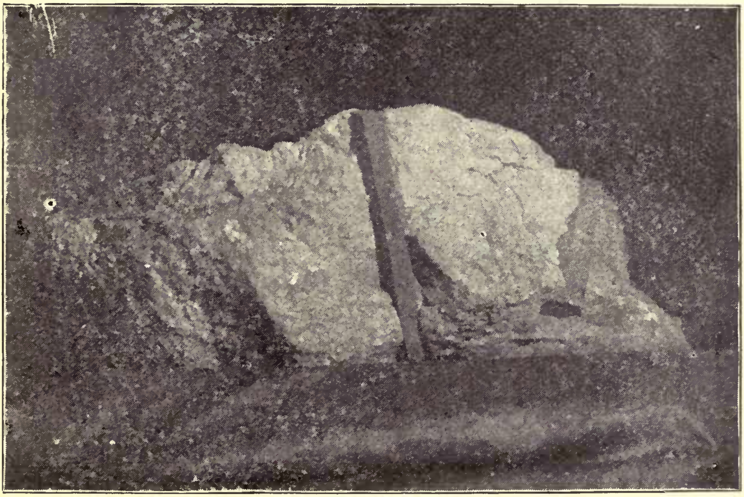

FIG. 57.

Beryl crystal in coarse-grained granite. Township of Lyndoch, Renfrew County, Ont. (Crystal two feet long).

Nepheline and **Sodalite** are sometimes spoken of as feldspathoid minerals, since they play the part of feldspar in igneous rocks, especially in syenite. When the latter rock contains these minerals in important quantities it is known as a nepheline or sodalite syenite. In such a case the percentage of alumina is higher than in that of the normal syenites. Frequently there is an excess of alumina in such rocks, which then crystallizes in the free or uncombined form, known as corundum. Nepheline syenite and related varieties of the rock are found at numerous points in the counties of Renfrew and Hastings and adjacent territory in eastern Ontario. They frequently carry corundum. Nepheline and sodalite, like the more acid feldspars, are silicates of alumina and the alkalies, soda being the characteristic alkali, although it is replaced to some extent by potash. Sodalite contains a few per cent. of sodium chloride. Both minerals fuse more or less readily, and gelatinize in acids. Nepheline is usually white in color and resembles quartz in lustre, but is readily distinguished by its fusibility and hardness. The characteristic color of sodalite is blue. The hardness of both minerals is 5.5 to 6, and specific gravity 2.1 to 2.6, that of sodalite being somewhat lower than that of nepheline. Crystals of either mineral are not common.

VII.—SULPHATES.

The sulphates are divided into two groups, (1) Hydrous, (2) Anhydrous. The important mineral, gypsum, belongs to the former. In the latter there are, among others, the sulphates of the alkaline earths—calcium, strontium and barium—known respectively as anhydrite, celestite and barite.

Gypsum ($CaSO_4 + 2H_2O$).—The variety of gypsum which occurs in distinct crystals of the monoclinic system or in transparent folia is known as selenite (Fig. 58). A fine-grained massive kind, which is opaque, is called alabaster. The mineral is also found in the fibrous form.

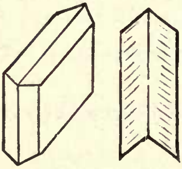

Fig. 58.
Gypsum crystal. The figure on the right represents a section through a twin crystal.

The lustre on some crystal faces is pearly and shining ; on others it is subvitreous.

The color is white, gray, red or some other shade.

One of the most distinctive characteristics of the mineral is the hardness, which is 1.5 to 2. The specific gravity is about 2.3.

Gypsum fuses rather easily, coloring the blowpipe flame reddish-yellow. It gives the sulphur reaction when reduced with soda. In the closed tube it gives off water and becomes opaque. It is soluble in hydrochloric acid.

The mineral often forms extensive beds interstratified with various sedimentary rocks, especially limestones. It is found in many parts of the United States, along the Grand River, near Lake Erie, in southern Ontario, and in the Maritime provinces.

Ignited so as to dehydrate it at a temperature not exceeding 260°, it again combines with water when moistened and becomes solid. Such ignited gypsum is known as plaster of Paris, which is used for making moulds, taking casts, and for producing a hard finish on walls. Gypsum is commonly employed as a fertilizer and is then called land plaster.

Two hydrous sulphates are of medicinal value. These are the minerals mirabilite or glauber salt, and epsomite or epsom salt. The former has the formula $Na_2SO_4 + 10H_2O$, and the latter $MgSO_4 + 7H_2O$. Both minerals give reactions, similar to those of gypsum, for water and sulphur. They are both very soluble in water.

Mirabilite falls to powder in the air and becomes anhydrous. Its solution gives with barium salts the reaction for sulphuric acid. Before the blowpipe the mineral gives an intense yellow flame. Since the mineral is readily obtainable for blowpipe practice, it may be added that epsomite on charcoal (before the blowpipe) fuses at first, and finally yields an infusible alkaline mass, which, when moistened with a solution of cobalt nitrate, gives a pink color on ignition.

ANHYDROUS SULPHATES.

There are three common anhydrous sulphates. The base of each is one of the alkaline earth metals,—calcium, strontium, or barium. They all crystallize in the orthorhombic system.

Anhydrite ($CaSO_4$).—The crystallization, hardness, and the absence of water distinguish this mineral from gypsum. Its non-effervesence in acids distinguishes it from carbonates, for which it might be mistaken. The cleavage is in three rectangular directions. The hardness is 3 to 3.5, and specific gravity 2.8 to 2.9. The lustre is vitreous to pearly. The color is usually white, but other shades are not uncommon.

Celestite ($SrSO_4$).—The cleavage of celestite crystals is perfect parallel to the basal plane and distinct in other directions. The mineral frequently occurs in radiated, fibrous masses. The lustre is vitreous to pearly. The hardness is 3 to 3.5, and the specific gravity about 3.9, which is less than that of barite. The color is white, often faint bluish (hence the name from *celestis,* celestial), or reddish. It is transparent to translucent, and very brittle.

Before the blowpipe, celestite decrepitates and fuses to a white pearl, coloring the flame strontia-red. With soda on charcoal it gives the sulphur reaction. It is insoluble in acids.

The mineral is usually associated with limestone or sandstone.

Celestite is used in the arts for the extraction of the oxide, strontia, which is employed in the manufacture of materials for fireworks, and in the refining of sugar. On this continent the closely related oxide of calcium, lime, is used for the latter purpose.

Barite ($BaSO_4$).—The crystals of this mineral are usually tabular in form, and they possess a perfect basal cleavage (Figs. 59, 60). It also occurs in globular, fibrous and lamellar forms.

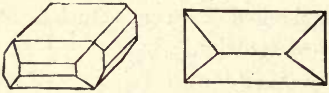

FIG. 59.
Barite crystals.

The lustre is vitreous, inclining to resinous, and at times pearly. The color is variable, but usually white. It is transparent to translucent or opaque.

The specific gravity, which is 4.3 to 4.7, serves to distinguish it from other minerals for which it might be mistaken. The mineral is frequently called heavy spar. The hardness is 2.5 to 3.5.

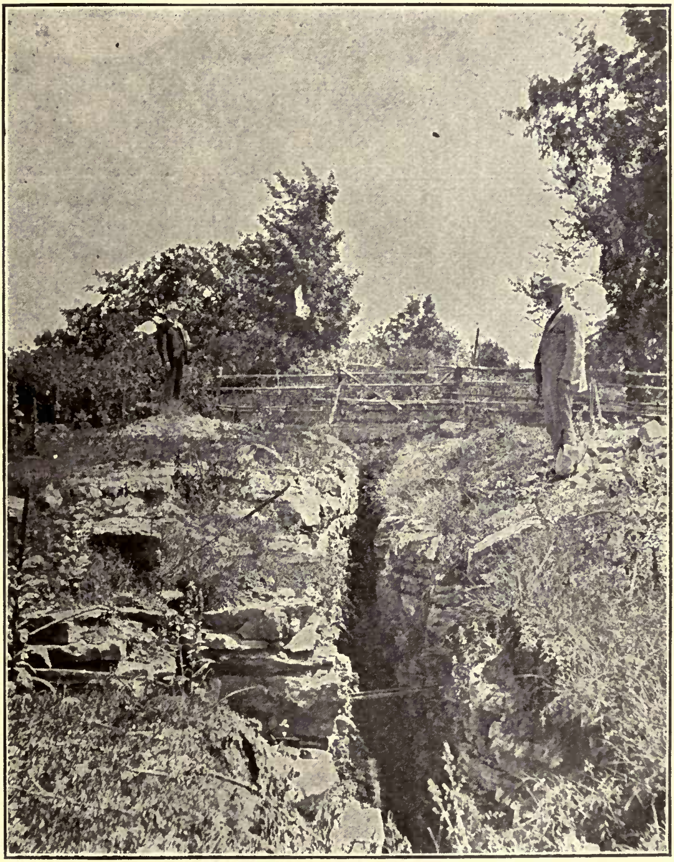

Fig. 60.

Vein from which barite has been mined. In horizontally-lying limestone, Elginburg, near Kingston, Ont. [Dr. H. M. Ami, G.S.C.]

Before the blowpipe it decrepitates and fuses, coloring the flame yellowish-green. It is insoluble in acids, and gives the reaction for sulphur when reduced on charcoal with soda (page 203).

Barite occurs commonly in veins with ores.

The white varieties are ground to an impalpable powder, and used as a white paint either alone or mixed with white lead. Barite paint is not discolored by acid fumes.

VIII.—PHOSPHATES.

There are a number of mineral phosphates, but the one of most common occurrence and of the greatest economic importance is calcium phosphate, which contains a certain percentage of either calcium chloride or calcium fluoride. This mineral is known as apatite. Its formula is $(CaF)Ca_4P_3O_{12}$. The fluorine may be replaced by chlorine.

Apatite.—This mineral crystallizes in the hexagonal system (Figs. 61, 62). Crystals from different districts vary in form. Those from southeastern Ontario and the adjoining part of the province of Quebec, which is one of the best known apatite regions, consist of a six-sided prism capped by a pyramid, which is sometimes truncated by the basal plane (Fig. 61). The mineral also occurs massive.

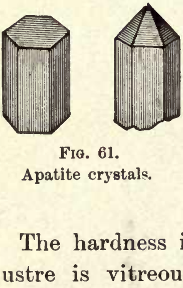

FIG. 61.
Apatite crystals.

The hardness is 5, and the specific gravity about 3. The lustre is vitreous inclining to sub-resinous. The color is usually sea-green or bluish-green, or reddish. The fracture is conchoidal and uneven. The mineral is brittle.

Before the blowpipe a splinter of apatite fuses with difficulty on the edges. The mineral in powder dissolves in nitric and hydrochloric acids. The solutions yield, with sulphuric acid, a copious white precipitate of calcium sulphate.

Apatite is found chiefly in metamorphic crystalline rocks; the more important deposits occur usually in crystalline limestone. The apatite of Canada is usually associated with amber mica, pyroxene and calcite. Minute, microscopic grains or needles of the mineral are present in most igneous rocks. These are the source of the phosphorus extracted from the soil by plants (see page 186).

The mineral was named from a Greek word which means to deceive, on account of the fact that the older mineralogists had mistaken it for various minerals.

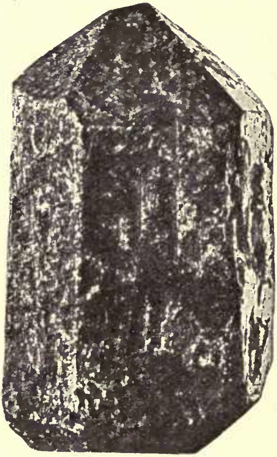

FIG. 62.
Apatite, hexagonal prism and pyramid. Frontenac County, Ont. (About one-half natural size.)

Apatite is used in the manufacture of a fertilizer. The mineral is treated with sulphuric acid which produces a soluble phosphate, very valuable as a food for plants. During late years little of the mineral has been mined in Canada (which formerly exported large quantities of it) owing to the discovery of large, lower grade, but more cheaply worked, deposits in the southern States. The material in these deposits consists largely of what is known as rock phosphate. Guano is another substance from which phosphate is obtained for use as a fertilizer. The element phosphorus, extracted from these minerals, is employed in the manufacture of certain kinds of matches and for other purposes.

REVIEW NOTES.

The beginner should not merely try to memorize the characteristics of minerals. He should compare specimens of one mineral with those of others. By doing this he will quickly learn the relative hardness and other characteristics of various species. He should first try to learn thoroughly the characters of a few common minerals. The number need not be more than eight or ten, among which should be the non-metallic minerals, quartz, feldspar, calcite, mica Among metallic varieties, he should first study iron pyrites, copper pyrites, magnetite and hematite.

The following groups contain minerals which the beginner is apt to mistake one for another, especially when in small grains or scales, and not well crystallized. From the descriptions which have been given, it will be seen that each can be identified by simple tests.

1. Native gold, native copper, iron pyrites, copper pyrites, yellow mica in minute scales.
2. Native silver, galena, mispickel, white mica in scales.
3. Quartz, feldspar, calcite, fluor spar.
4. Graphite, molybdenite.
5. Schorl, anthracite.
6. Apatite, beryl.

HARDNESS.

For comparing the hardness of minerals, the following list, known as the *scale of hardness*, is commonly used. The number before each mineral represents its hardness, that of talc being 1, gypsum 2, and so on:—

1. Talc.
2. Gypsum.
3. Calcite.
4. Fluor Spar.
5. Apatite.
6. Orthoclase.
7. Quartz.
8. Topaz.
9. Corundum.
10. Diamond.

It will be seen that these are all non-metallic minerals. For practice in comparing the hardness of minerals with a metallic lustre, draw up a list of eight or ten, no two of which possess the same hardness.

The reader will have little difficulty in obtaining specimens of each of the minerals in the scale, with the exception of the diamond. Some of them can be collected in almost any neighborhood, while others can be procured by exchange, or at little cost by purchase. Crystals, with smooth surfaces, or cleavage pieces, are the most serviceable. The specimens should be fresh, and free from admixture with other minerals.

SPECIFIC GRAVITY.

Much use can be made of specific gravity. With a little practice one can say whether that of a specimen is high, low, or medium. By this means barite, for example, can be readily distinguished in the hand from calcite, fluor spar or other mineral for which the beginner might mistake it.

Among non-metallic minerals the average specific gravity ranges from 2.6 to 3; for example, quartz, 2.66; calcite, 2.7; the feldspars, 2.6 to 2.75. A specific gravity of 2.5 or less is low, and is characteristic of soft minerals; for example, gypsum, 2.3. A specific gravity above 3.5 is relatively high for non-metallic minerals; for example, diamond, 3.52; corundum, 3.95 to 4.10; celestite, 3.95 to 3.97; barite, 4.5.

Minerals with a metallic lustre have an average specific gravity of about 5:—Iron pyrites, 4.95 to 5.10; hematite, 5.2 to 5.3; magnetite, 5.18. That of the following is high:—Galena, 7.5; copper, 8.8 to 8.9; silver, 10.1 to 11.1; lead, 11.4; platinum, 14 to 19; native gold, 15.6 to 19.3. The variation in different specimens is due to the presence of other substances in admixture. Pure gold, for example, has a specific gravity of 19.33, but the metal is never found perfectly pure in nature.

The lustre, color, streak and other characters of common minerals, have been summarized in the table on pages 50 to 53.

Crystals.

As a review exercise in crystallography it will be well to prepare a list of minerals which crystallize in the isometric system. Similar lists should be prepared for each of the other five systems.

Localities.

In order to systematize his knowledge of mineral localities, the reader should draw up lists, consulting the text and the index of this book. For example, under the heading of copper pyrites give localities in which this mineral is found. On the other hand, under the heading of a locality, district or territory, give the names of minerals which are found therein.

Further notes on mineral localities are given in Part IV.

The reader should look up the pronunciation of the names of minerals and rocks, concerning which he is in doubt, in some standard dictionary. A knowledge of the origin of the names is also of value.

PART III

ROCKS AND ROCK STRUCTURES.

Classification of Rocks.*—According to the commonly accepted theory, the earth and the other members of the solar system were, at one time, in a fused or molten condition; hence the first rocks formed on our globe (through the cooling of the molten mass) belonged to the class known as the Igneous, or heat-formed rocks. These rocks are still being formed (as shown by volcanoes) through the cooling of fluid matter which rises from depths in the interior of the earth, through fissures in the crust, to or towards the surface.

Igneous rocks which have solidified at the earth's surface, or have been exposed by the wearing away or denudation of overlying rocks, are acted on by the atmosphere, water and other agencies, and broken down, to a greater or less extent, to form gravel, sand and clay. The materials thus formed, which are fragmental in nature, together with rocks formed by the deposition of the remains of plants and animals, make up the greater part of the class known as Aqueous, or water-formed rocks. They are given this name on account of water being the chief agent in their formation. They are known also under the names sedimentary, fragmental, and clastic.

The sorting action of water on the loose material into which rock masses are broken may be seen along the shore of any lake. The coarsest material, gravel, is deposited near the shore; while the sand is deposited in layers in deeper water; and the finest material, or clay, is deposited still farther from the shore line. Through the effects of pressure and cement substances, these loose products are solidified in time into beds or strata of conglomerate, sandstone and shale (Figs. 72, 73, 81, 83).

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* The indoor or laboratory study of rocks is known as *Lithology*. The study of larger structures, such as Jointing and Stratification, is called *Petrology*. *Petrography* is a broader term and embraces both lithology and petrology. The three terms are, however, not always used in the way here described.

If these aqueous rocks are subjected to greater pressure and heat, they are rendered very compact, and their characters are much altered. They become more or less crystalline in appearance and are then known as Metamorphic or altered rocks, or as the Crystalline schists.

Metamorphic rocks are also formed from those of the igneous class through the agency of pressure and chemical action. Thus, while some gneisses are known to be altered aqueous rocks, it has been proved that others have been formed through the alteration or metamorphism of igneous rocks.

We thus have three kinds, or three great classes of rocks, making up the crust or outer part of the earth, viz., the Igneous, Aqueous and Metamorphic rocks (see pages 21, 22).

A.—IGNEOUS ROCKS.

Volcanic and Plutonic Rocks.—The earth is constantly losing heat and diminishing in size. The interior as it loses heat tends to shrink away from the external cool and solid crust. This causes the crust to become folded and wrinkled, as the cooling goes on. In places the side or lateral pressure on the folds becomes so great that they are cracked and broken across. The fissures or cracks thus formed in the crust sometimes reach to such depths that the highly heated matter of the interior finds a passage to the surface. On cooling it gives rise to surface-formed igneous rocks, or, as they are generally called, volcanic rocks. The material of which these are composed, on exposure at the surface of the earth, cools quickly, after the manner of the molten material which is drawn from a furnace. Hence we find that volcanic rocks are often slag-like or glassy in appearance. Only a part of the injected molten matter will reach the surface. Much of it is arrested some distance below, where being out of contact with the air and surrounded by rocks, which are poor conductors, it loses its heat or cools slowly, and gives rise to rocks which are coarse grained and crystalline, and not glassy or slag-like in appearance. Igneous rocks of this class are called plutonic rocks, since they are formed deep down beneath the surface of the earth. Fissures filled with igneous rocks are known as dikes (Figs. 63. 75, 76, 87)

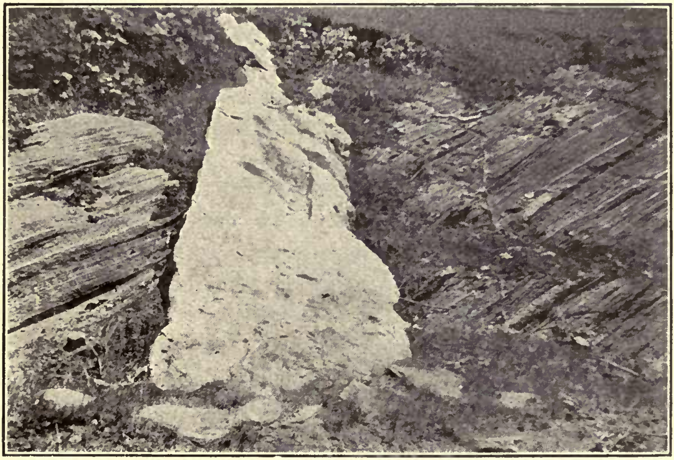

FIG. 63.—A dike of light-colored granite cutting crystalline limestone. Chandos Township, Peterborough County, Ont.
[DR. A. E. BARLOW, G.S.C.]

It is not to be inferred from what is said in the preceding paragraph that the earth has a molten interior. While the material, a certain distance beneath the surface, is at a high temperature, the pressure is great enough to keep it in the solid form. Where the pressure is relieved by folding or fissuring, the highly heated matter becomes molten or fluid.

Veins.—Some of the fissures formed by the fracturing of the earth's crust do not extend down to the highly heated interior, and hence are not filled with molten material. In course of time, however, most of these fissures are filled with mineral matter, which is deposited from solution in the waters that circulate through the crevices and openings in the rocks (pages 23, 173). The fissures thus filled with mineral matter are known as veins (Figs. 15, 30, 60). It is from these veins that some of the finest mineral specimens and most valuable ores are obtained. While dikes and fissure veins are similar in form, the latter are of aqueous origin, while the former are of igneous formation.

It is natural that the older rocks should in most cases be more broken and fractured than the newer; hence veins are more frequently found in them. In the process of folding, openings are made between the beds of rocks, and, moreover, cavities are made through the solvent action of water. These openings and cavities are filled in the course of time in the same way, as are some fissures, by the deposition of material from solution. We thus get mineral deposits or ore bodies of various forms (page 171).

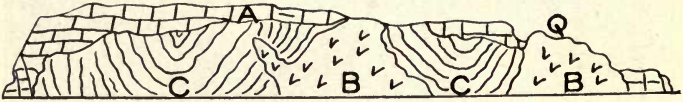

Fig. 64.

(A) Limestone. (B) Granite. (C) Gneiss. (Q) Granite Quarry.
Section across Barriefield Common, Kingston.
(A) Limestone (an aqueous rock). (B) Granite (an igneous rock). (C) Gneiss (a metamorphic rock).

If a series of beds of rocks has been folded and then exposed to erosive or breaking-down action, through the agency of water and the atmosphere, the tops of the folds may be worn off. We then get a structure such as is shown by the gneiss C in fig. 64. (See also Figs. 78, 79.)

Rocks of four ages are shown in the section, viz.: gneiss; granite, which cuts through the gneiss and is therefore the younger of the two; limestone, which overlies both the granite and the gneiss and contains fragments of the former, and is the youngest of the three; glacial boulders and other loose material, which overlie the limestone and are the youngest rocks present.

Several common geological terms may be explained by means of the section, *e.g.*, "contact," the point of junction of two different rocks, *e.g.*, the limestone with the gneiss or granite; "unconformity," the beds of limestone lying on the upturned edges of the gneiss. The layers of the gneiss make an angle with the horizontal. The gneiss is therefore said to "dip" at a certain angle. The horizontal direction or the course of the upturned edges, which is perpendicular to the line of dip, is spoken of as the "strike." The granite appears at the surface of the ground, or forms an "outcrop." A mass of igneous rock, such as the granite here shown, exposed at the surface in a more or less rounded or irregular form, is spoken of as a "boss." Narrow fissures in the gneiss are filled by granite. Such structures are known as "dikes." The foldings in the gneiss show "anticlines" or ridge-like forms, and "synclines" or trough-like forms. The bedded structure in the limestone is spoken of as "stratification," each bed being called a stratum. The gneiss shows a layer-like structure also, but the layers are not so regular as those in the limestone, and are more or less finely bent and crumpled. This structure in gneiss and other crystalline rocks is spoken of as "schistosity"—the rocks are said to have a schistose structure. The granite is not arranged in layers, and is called a "massive" rock. Several of these terms are explained more fully on pages 141 to 150.

NAMES OF IGNEOUS ROCKS.

The igneous rocks may be divided, as we have seen, into two groups—plutonic and volcanic. The members of each group are again subdivided, according to the percentage of silica they contain, into acid, intermediate and basic rocks. The divisions are made approximately as follows:—If a rock contains over 65 per cent. of silica, it is spoken of as an acid rock; if its percentage of silica is between 50 and 65, it is said to be intermediate in composition. Rocks containing less than 50 per cent. of silica are said to be basic.

The names given to Igneous rocks, unless they are glasses, depend on the minerals they contain—hence also on their chemical composition—and on their texture, that is on the form and arrangement of their constituent minerals.

The following tabular arrangement of the Igneous rocks shows the way in which they are classified according to the description given above. Only the more commonly occurring rocks are shown in the table. The minerals named are those which are found in the more characteristic varieties of each rock. Hornblende, for example, may be replaced in whole or in part by biotite or by pyroxene, and *vice versa.*

	Chief feldspar = Orthoclase.		Chief feldspar = Plagioclase.	
PLUTONIC (Texture, coarse-grained).	with usually Mica (or) (and) Hornblende (or) (and) Augite.		with Hornblende (or) (and) Mica	with Pyroxene.
	with Quartz.	without Quartz.		
	Granite.	**Syenite.**	**Diorite.**	**Gabbro.**
VOLCANIC (Texture, fine-grained or more or less glassy).	**Rhyolite.**	**Trachyte.**	**Andesite.**	**Basalt.** **Diabase.**
	Obsidian. **Pitchstone.** **Pumice.**			

The mineralogical composition of the plutonic rocks can be made out by a glance at the table; for example, it is seen that we may have a syenite which is composed of mica and orthoclase, or a granite which has quartz, orthoclase and hornblende as essential constituents.

Each volcanic rock corresponds in chemical composition, especially in percentage of silica, to the plutonic rock in the same vertical column. Usually, however, the volcanic rocks are incompletely crystallized. They contain more or less glass, which is represented in the corresponding plutonic rocks by mineral grains.

It will be seen that among the plutonic rocks granite, since it contains the more acidic minerals, stands at the acidic end of the series, and gabbro at the basic. Similarly the percentage of silica decreases as we pass from rhyolite through trachyte and andesite to basalt. (See the descriptions of mica, feldspar, amphibole, and pyroxene, pages 88 to 95.)

There are no hard and fast lines between rocks. We find one group or class passing gradually into another. Thus, one might get a rock which could be called either a basic granite or an acid diorite. Hence, too much stress should not be placed on a name. If we know the characteristics of a rock, that is, can give a description of it, it matters very little for our own convenience whether we give a name to it or not. A name serves merely as a short general description; but, as many closely related rocks, varieties of granite for example, differ from one another in so many particulars, it is necessary for us, if we wish to give the characteristics of a certain granite, to state something more than its mere name. In most cases, the characters of the Aqueous rocks are less difficult to determine than are those of the Igneous class, and no tabular arrangement is required in their description. The more common Aqueous rocks, as we have seen, are conglomerate, sandstone, shale and limestone (pages 21, 22). The Metamorphic rocks also do not require a complex classification (page 22). Some of the more common members of this class are gneiss, mica schist, quartzite, slate, and crystalline limestone.

Representative Plutonic Rocks.

GRANITE.

Granites are coarse or medium-grained rocks, gray or light red in color, composed typically of quartz, orthoclase, or other acid feldspar, and mica, either biotite or muscovite, or both. Mica may be replaced in whole or in part by hornblende, and rarely by augite. The ferro-magnesian constituents, biotite and hornblende, in granite are often decayed, and the feldspar is often more or less altered to kaolinite, when the rock has been subjected to atmospheric influences. Some of the most common accessory minerals of granite are magnetite, apatite, tourmaline and zircon. Cassiterite, or tin-stone, is also found in certain varieties of the rock.

Granites are found in bosses and dikes cutting through other rocks, and they are often overlain by sedimentary material. They frequently show a porphyritic texture, *i.e.*, part of the feldspar or other minerals occurs in well defined crystals set through the mass (Figs. 65, 71).

Granite pegmatite is a very coarse-grained rock, made up of the same minerals as are found in ordinary granite. Quartz and light colored feldspar, however, predominate in this rock, and mica, when present, is usually light colored. The rock is often a storehouse for rare and valuable minerals, among which may be mentioned tin-stone, tourmaline and beryl. Graphic granite is a variety in which the gray quartz is so arranged through the white feldspar as to present the appearance of characters in the ancient Grecian or Hebrew alphabet (Fig. 66).

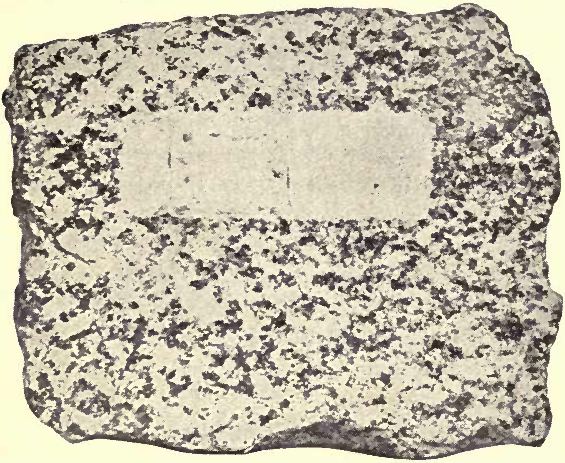

FIG. 65.

Granite-Porphyry. The crystal of feldspar looks like a label on the illustration.

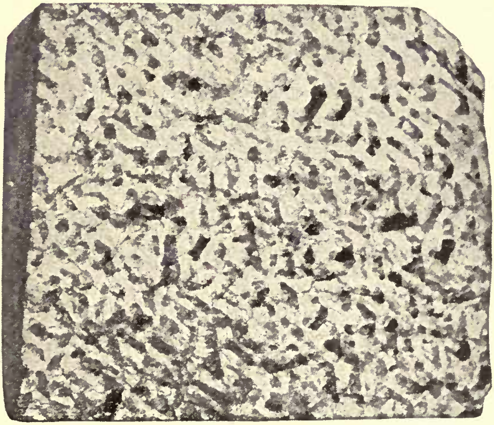

FIG. 66.

Graphic Granite. Gray quartz is set in white feldspar.

Granite and other plutonic rocks are found in so many districts that it is not considered necessary to give the names of localities.

The value of a granite mass for industrial purposes depends on a number of factors, among which might be mentioned color, homogeneity in texture, power of resisting decay, ease in quarrying, and facilities for transportation. An altered granite found in the gold regions of northwestern Ontario, and in other parts of the world, is sometimes known as protogine, but the name is not used so much as formerly. Granites have in some cases been changed into gneiss through the action of pressure and other agencies.

SYENITE.

This rock is coarse to medium-grained and it usually has a reddish or gray color. It has much the appearance of granite, and differs from it only in the absence of quartz. Hence a syenite may be called a quartzless granite. While the percentage of silica in granite, on account of the presence of quartz, is high, 65 to 80, making an acid rock, the silica in syenite is in a considerably lower percentage. Syenite is therefore said to be a rock of intermediate composition—its percentage of silica lying between that of granite and the basic rocks, or those low in silica. A highly interesting rock, known as nepheline syenite, is found in some parts of the world. In it the rare mineral nepheline plays the part of a feldspar.

In describing a granite, syenite, or other igneous rock, it is necessary to state the mineralogical composition. For example, we may have a hornblende syenite, or a biotite syenite, and so on.

Syenite is commonly called granite in commerce.

DIORITE.

This is usually a rather coarse-grained rock, darker in color than syenite, from which it differs by having a soda-lime feldspar, instead of orthoclase, as its chief feldspathic constituent. Typical diorite consists essentially of plagioclase and hornblende.

Since it is often difficult to distinguish diorite in hand specimens from other dark colored medium- or coarse-grained igneous rocks, the name is frequently used as a convenient field term for all such rocks.

GABBRO.

Gabbro is often very coarse-grained and usually dark in color. It contains a lower percentage of silica than diorite, and typical specimens are composed essentially of basic plagioclase and the variety of pyroxene known as diallage. Where hypersthene is present as an essential constituent, the rock is known as norite. Anorthosite, a rock related to gabbro, consists essentially of lime-soda feldspar. It may be mistaken for crystalline limestone, but is harder. Gabbro often contains much magnetite, and it is believed by some authorities that certain magnetite deposits found associated with this rock are of igneous origin, and have been formed at the same time and out of the same molten mass as the gabbro with which they are associated. A similar theory has been proposed to account for the origin of the nickeliferous pyrrhotite deposits of Sudbury, which are associated with gabbro-like rocks.

Very coarse-grained varieties of gabbro, diorite and syenite, like similar varieties of granite, are called pegmatites, and are known as syenite-pegmatite and so on.

Representative Volcanic Rocks.

OBSIDIAN.

This is a natural glass. It is usually a volcanic representative of the plutonic granite, as the two rocks frequently agree in chemical composition. Their textural difference, one being a glass and the other a coarsely crystalline granular rock, is to be accounted for by the difference in the conditions under which they were formed. Granite originated deep down beneath the surface of the earth by the gradual or slow cooling of molten matter, and has been exposed by denudation. On the other hand, the molten material from which obsidian was formed poured out at the surface of the earth and lost heat so quickly that there was not time for the constituent molecules to arrange themselves in mineral grains. The whole mass became solid in a comparatively short time.

Occasionally obsidian has a composition similar to that of plutonic rocks other than granite.

Rhyolite is like granite in chemical composition, but is more or less glassy. Sometimes it is composed of crystals of orthoclase and granules of quartz set in a glassy groundmass.

PUMICE.

This rock is a porous or vesicular obsidian. Pitchstone, which is resinous in appearance, may be looked upon as a hydrous obsidian. The name felsite is sometimes given to a devitrified glassy rock, fine-grained and compact in structure, and consisting of orthoclase intimately mixed with some quartz. It has a flint-like fracture, and sometimes is very dull or stony in appearance. The term felsite is, however, like the names of some other rocks, so differently used by different writers that its reputation as a rock name is lost. Specimens of pumice can be obtained in many drug stores.

TRACHYTE

Trachyte is a volcanic rock which corresponds to syenite in chemical composition. It is light gray in color and presents a dull appearance. At times it looks somewhat like a fine-grained limestone, but crystals of feldspar can usually be detected in the fine-grained ground-mass.

ANDESITE.

This is the volcanic representative of diorite. It is so named on account of the fact that typical outcrops of it are found in the Andes mountains. It is also met with in the western States, British Columbia, and other parts of the world.

Andesite is usually darker in color than trachyte, but at times it is impossible to distinguish the one rock from the other in hand specimens.

BASALT.

Basalt corresponds in chemical and mineralogical composition to gabbro, and is one of its volcanic representatives. It is a dark, heavy, close-grained rock, and is often known under the name of trap, which is a convenient field term. It often possesses a columnar structure, and frequently contains small cavities through it, which are filled with agates or other minerals (Figs. 67, 68). Since these cavities are frequently almond-shaped, the rock, when containing them, is said to have an amygdaloidal texture. Basalt, and the closely related diabase, are characteristic rocks on the north shore of Lake Superior.

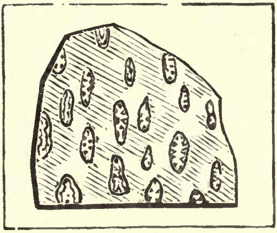

FIG. 67.
Amygdaloidal Texture in Basalt.

DIABASE.

Diabase is another volcanic representative of gabbro. It differs from basalt in structure. Typically, it consists of the two essential minerals, plagioclase and augite, but olivine may also be present, when the rock is known as olivine diabase. Diabase tends to weather at the surface of the ground into spheroidal or ball-like masses (Fig. 69). When examined in thin sections or slices under the microscope the plagioclase

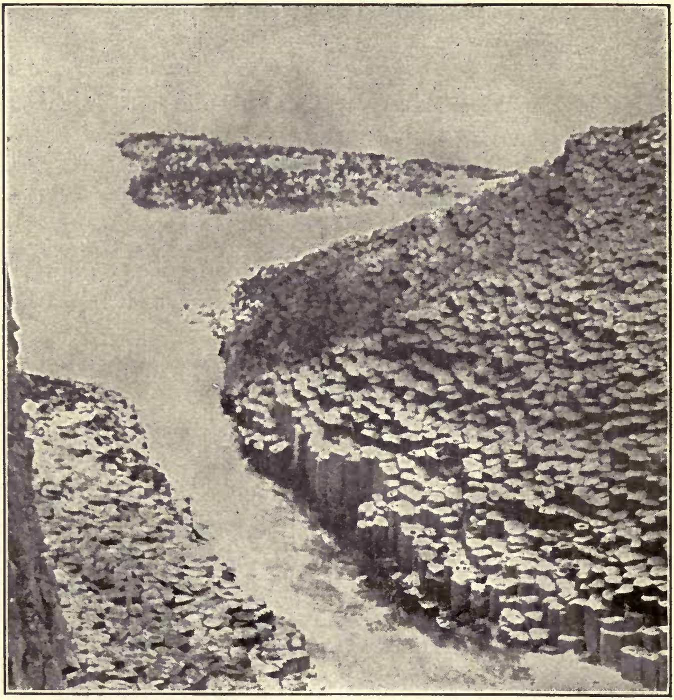

Fig. 68.

Columnar structure in Basalt.

is seen to be in lath-like strips which are set into the augite. On a weathered surface of the rock, in hand specimens, the plagioclase laths may be seen as very fine, short, white lines, a characteristic by which the rock may be distinguished. Of

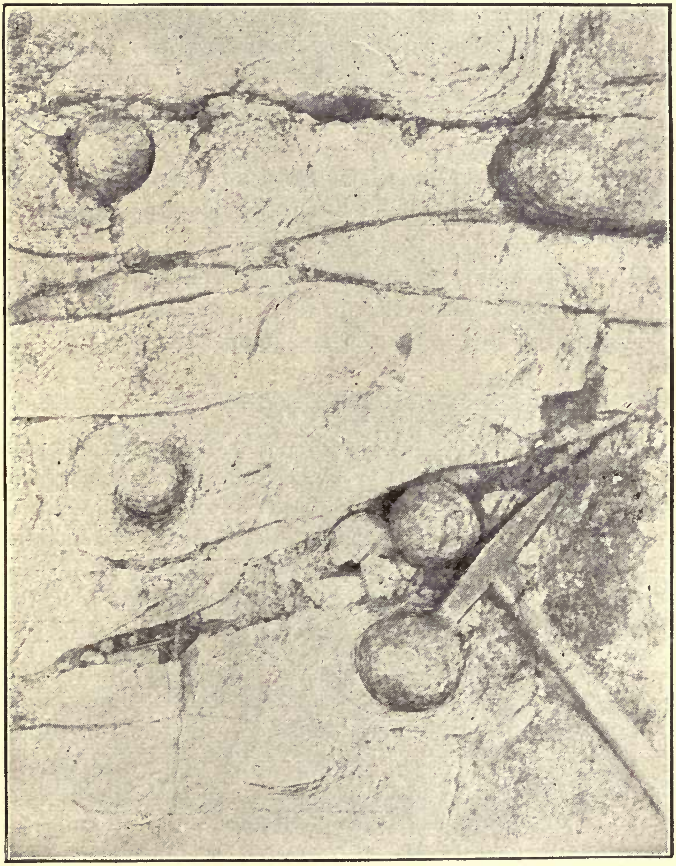

Fig. 69.

Spheroidal weathering in Diabase. Quinze River, Que.

course if the surface examined is much rusted or decomposed the lines do not come out. Various accessory minerals are found in the rock.

Boulders of basalt or diabase are to be found in most districts in the northern States and Canada. As it will usually be difficult to distinguish the one rock from the other, the name trap, which covers both of them, can be applied to any fine-grained, compact, dark colored, massive rock. Farmers frequently call the boulders of these rocks "hard heads."

In most districts in which exposures of igneous rocks occur, the reader will find outcrops of diabase or basalt in dikes or masses.

In western mining camps the name porphyry is applied to almost every rock that occurs in dikes or sheets. Such rocks in most cases belong to the volcanic group.

B.—AQUEOUS ROCKS.

The chief characteristics and the origin of the class of rocks to which the name aqueous is applied have been described on a preceding page. It has also been shown that the names fragmental, sedimentary, and clastic are used in about the same sense as aqueous. Since the members of this class usually occur in well defined beds or strata they are frequently known as the stratified rocks (Figs. 5, 72, 73, 81, 83, 85).

We have seen that sand, gravel and clay are laid down mechanically by the action of water. It has also been stated that, while a few limestones are of chemical origin, being precipitated from solution in water, most limestones are of organic origin, being formed by the accumulation, under water, of the calcareous shells and hard parts of animals. According to their mode of formation, aqueous rocks can therefore be divided into three groups, viz., mechanically.

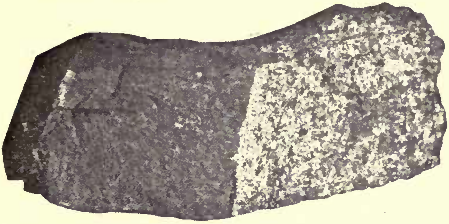

FIG. 70.

Trap in contact with granite. The specimen was taken at the edge of a trap dike.

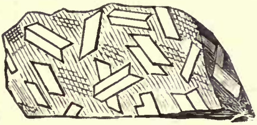

FIG. 71.

Volcanic rock with porphyritic texture.

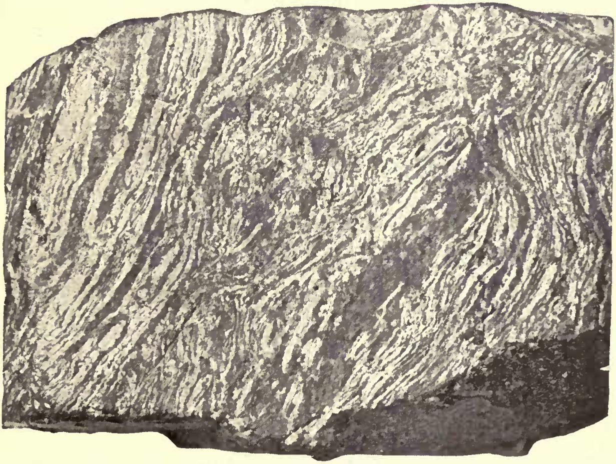

FIG. 71 *bis*.

Flow structure in a volcanic rock (produced by movement in molten material).

chemically, or organically formed. It should, however, be remembered that, as in the case of the igneous rocks, no hard and fast lines can be drawn between these three groups of aqueous rocks. Frequently, for example, we find calcareous sandstones in which the calcareous constituent may be either of chemical or organic origin. At other times limestones are found which contain more or less clay or sand.

There are two groups of rocks, of minor importance, to which the name fragmental is properly applied, but which do not belong to the aqueous class, since water plays no part in their deposition. These are (1) the wind-deposited or aeolian rocks, *e.g.*, sand dunes, and (2) the accumulations of fragments of various sizes which are thrown out from volcanoes (Figs. 21, 22). The latter are known as the volcanic fragmental group. The material composing them varies in form from fine dust or sand to that which is made up of large blocks. The coarser deposits of this kind frequently contain blocks which are more or less rounded. They then resemble the ordinary water-deposited conglomerates, but can frequently be rather readily distinguished by the fact that they are made up of fragments of various sizes and shapes. They thus do not show the sorting effect of water. Such deposits of coarse volcanic fragmental material are known as agglomerate. A rough sorting is accomplished by the large blocks falling near the vents, while the lighter particles may be carried for a long distance in the air. When such material has fallen into, or been worked over, by water, it is arranged in beds which have the appearance of ordinary sand and gravel deposits. The finer-grained layers are then known as ash-beds, feldspathic sandstones, and so on, depending on the predominant constituents. The general name, volcanic tuff or tufa, is also used for these deposits. Tufaceous beds may contain a greater or less amount of ordinary sedimentary material.

1. **Arenaceous Rocks.**—The name arenaceous (from *arena*, sand) is applied to rocks which contain more or less quartz in the form of grains. Ordinary sand and sandstone, which have been described on a preceding page, come under this heading. Certain limestones, clays, or shales at times contain quartz grains. We thus have arenaceous limestones and shales.

Sandstones, as already stated, usually contain grains of other minerals and rocks, in addition to quartz, especially those minerals which are not easily decomposed by atmospheric agencies, such as magnetite and garnet, and occasionally native gold and other rare species.

Sandstones vary greatly in color and other characters. The color depends on the percentage and state of oxidation of the iron present. Brown and red sandstones are popular building materials in some localities. Their colors are due to the presence of ferric iron.

If a sandstone, in being cut into building blocks, does not tend to separate into layers, but can be worked almost as readily in one direction as in another, it is known as a freestone. When the rock splits easily into slabs, it is called flagstone.

On another page it was stated that, when sandstones are subjected to pressure and heat, accompanied by more or less chemical action, they are changed to a more compact rock, which has, usually, a brighter appearance, and is known as quartzite. This rock belongs to the metamorphic class.

Limestones at times break down into a mass of grains with the size of those in ordinary sand. We then have what may be called a limestone sand, using the name sand in a wide sense. Under certain atmospheric conditions, other rocks break down and give rise to material with the texture of common sand. A mass formed by the breaking down of granite, and consisting of grains of feldspar, quartz, and other minerals, is known as arkose. If such a rock consists essentially of quartz and feldspar, it may be called a feldspathic sandstone.

Conglomerates, which have been described on a preceding page, vary greatly in composition, being built up of the rounded fragments of various minerals and rocks. They are closely related to sandstones (Figs. 8, 73).

The cement materials, which bind sandstones and conglomerates together, are usually either calcium carbonate, silica, or iron oxide. These substances are deposited from solution in the waters which percolate through the, at first, loosely coherent beds of sand and gravel. In the boulders of sandstone or conglomerate, which the reader may discover in his neighborhood, the cement substance will usually be silica, in the form of quartz. In some sandstones it will be found difficult to distinguish between the cement substance and the original grains of quartz. The grains have simply increased in size by the deposition of silica

Fossils are usually not so abundant in sandstones and conglomerates as in limestones.

2. **Argillacecus Rocks.**—The term argillaceous is applied to clays and other aqueous rocks which contain kaolinite. Clays have already been briefly described in discussing the characteristics of kaolinite. They sometimes show well defined bedding, and at other times they are massive and contain numerous scattered boulders (Figs. 5, 6, 72). The term boulder-clay or till is applied to the latter class of clays which are quite common in the northern States and Canada. These massive, boulder clays are glacial deposits.

The uses made of clays have already been mentioned.

Sandstones and limestones, which contain more or less clay or kaolinite, are known as argillaceous sandstones and argillaceous limestones, respectively.

Most clays contain more or less iron, in various states of oxidation, calcium carbonate, quartz and other minerals, and pass into sand or sandstones on the one hand, and into marl or limestone on the other. The purest clays, known as fire clays, since they are used in the manufacture of brick which withstand a high temperature, are found in association with coal beds. In the process of change, which the entombed plant-remains undergo to form coal, carbonic acid gas and other

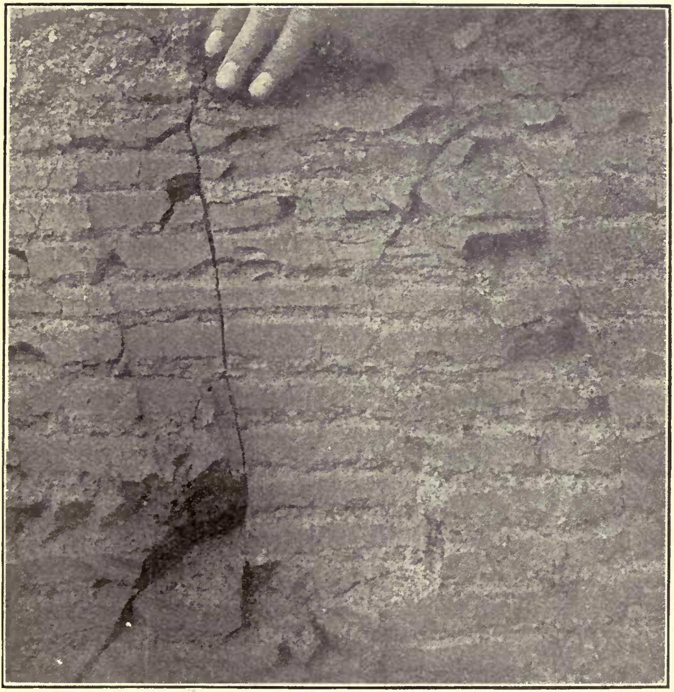

FIG. 72.

Bedded Clay. This illustration represents a closer view of a part of the clay bank shown in Fig. 5. The alternate lighter-colored layers are more or less marly.

compounds are expelled which, with water, tend to leach the alkalies and other impurities out of the clay. The clay beds in many cases represent the soil, thus purified, on which the coal plants grew.

Deposits of kaolin are sometimes found, especially in non-glaciated countries, at or near their source of origin. They are formed by the weathering of granite or other feldspathic rocks in place. Such deposits have not been worked over by glaciers or water, and thus have not had impurities introduced into them.

The occurrence of concretions in clay has been referred to on page 10. They frequently form around a shell or the body of an animal, or around a pebble. They contain calcareous or other cementing material. In some cases the cement is organic, exuding from the enclosed remains. Remarkable concretions are sometimes found in sandstones (Fig. 73).

The following table shows the difference in percentage composition between (1) kaolinite, with theoretical percentage, (2) a fire clay, (3) an ordinary brick clay :—

	1.	*2.*	*3.*
Silica	46.50	49.64	59.96
Alumina	39.57	34.78	19.58
Ferric oxide	....	1.80	5.86
Lime	....	.68	2.62
Magnesia	....	.41	2.30
Potash	....	.41	2.57
Soda	....	....	2.48
Sulphur trioxide	....	....	.23
Water	13.93	....	....
Water, carbon dioxide, etc.	....	....	5.00

It will be seen that the brick clay contains some of the elements which are essential as plant food. Such a clay represents the soil of many districts.

The relation between slate and clay is described on page 10. Shale is a laminated clay, less compact than slate, and more or less friable.

3. Calcareous Rocks.—The important and wide-spread group of rocks known as limestones come under this heading. Typically they are composed of calcium carbonate, in the form of calcite, but they show great variety in chemical composition.

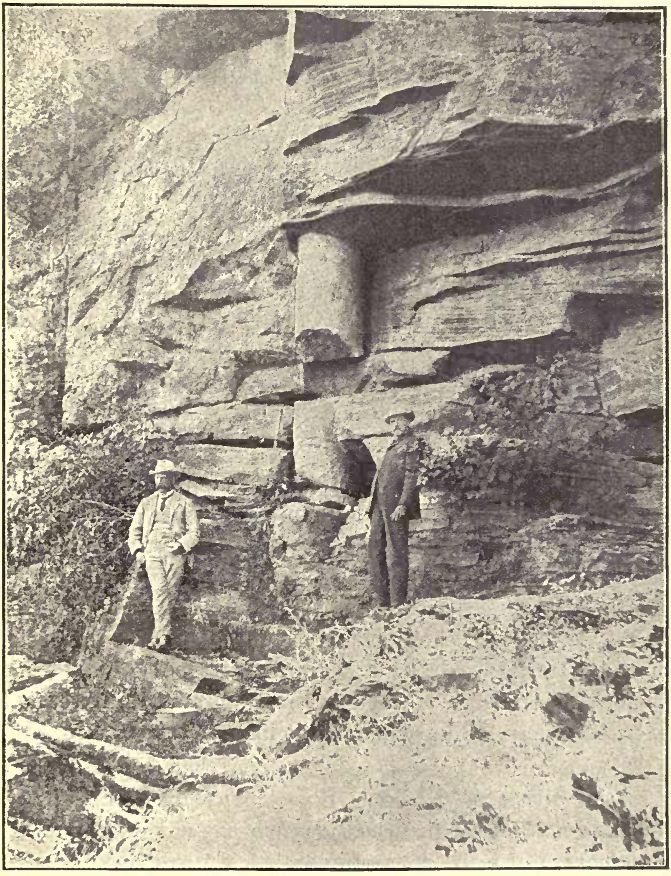

Fig. 73.

Concretion, resembling the trunk of a tree, in sandstone quarry on the Rideau Canal, near Kingston Mills, Ont. [Dr. H. M. Ami, G.S.C.]

Frequently, the element calcium is replaced to a greater or less extent by magnesium. The term magnesian is applied to limestones which contain a few per cent. of magnesium carbonate, while if fifteen or twenty per cent. of this compound is present the rock is called a dolomitic limestone.

Most limestones are of organic origin and have been formed, as already shown, by the accumulation of the calcareous shells or other hard parts of animals. This accumulation has generally taken place beneath the waters of the sea. Hence most limestones are said to be of marine origin. The groups of animals which give rise to these deposits are chiefly the corals and mollusca. Deposits of similar origin, but smaller in size, are also formed in fresh water. These are represented by many of the marl or clayey limestone deposits, found in the basins of small lakes and swamps, which are extensively employed in the manufacture of Portland cement. Some limestones are formed, however, by the precipitation of calcium carbonate from solution in water.

Limestones are great store houses for fossils (Figs. 10, 74). The remains of corals at times are found to have had the calcium carbonate replaced by silica, and hence are said to be silicified. The great majority of the calcareous remains, of which many limestones were originally composed, have been broken up through pressure and the solvent action of water. Wave action has broken down coral reefs, and the deposition of the material produced has given rise to limestones which show little evidence of their origin. Coral reefs have, however, been detected in some ancient limestone formations.

The carbonate present in limestones has originally been essentially that of calcium. Since many limestones, as we now find them, contain a considerable amount of magnesium carbonate, it has been suggested that the calcium has been replaced by the action of magnesium chloride, which is present in appreciable amounts in sea water.

The following table shows the percentage composition of two limestones, similar in appearance, which were submitted to analysis:—

	No. 1.		*No. 2.*
Lime..................	30.84	....	54.06
Magnesia.............	21.11	....	.55
Carbon dioxide........	47.40	....	42.90

The impurities present in each case are chiefly small quantities of silica, ferric oxide and alumina.

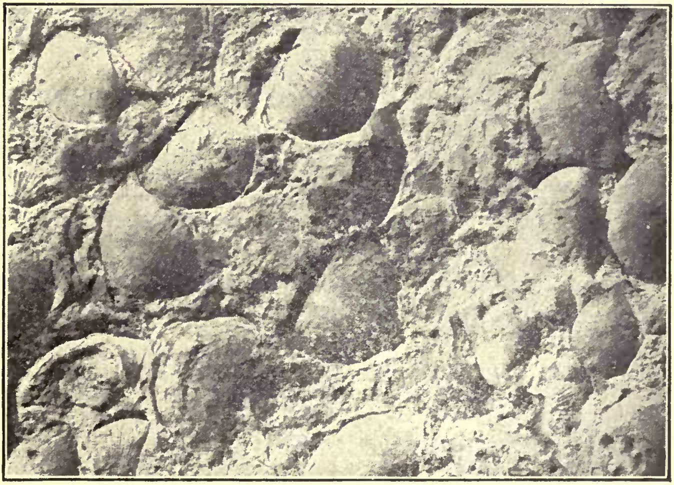

FIG. 74.

Limestone containing shells. Cape Smyth, Manitoulin Island, Lake Huron. [Dr. H. M. AMI, G.S.C.]

The uses to which limestones are put are much more numerous than are those of any other rock. Limestone or some of its products are made use of in every neighborhood and in almost every household. The following are among a few of the more important uses of the rock—manufacture of lime, as a flux in smelting ores, stone for building, manufacture of Portland cement, natural rock cement. Very fine grained, pure limestones of even texture are of great importance in lithography. Some of the common uses of lime are: in mortar, as a disinfectant, white-wash, in agriculture, and in beet-root sugar manufacture.

Limestones of special composition are required for certain purposes. For example, in the manufacture of Portland cement, the rock should not have more than two or three per cent. of magnesia. Similar rock is required for calcium carbide. On the other hand, in the preparation of wood pulp by what is known as the sulphite process, a rock as high in magnesia as is obtainable is desirable.

Limestones vary as greatly in structure as in chemical composition. The more characteristic kinds occur in compact and well defined beds of varying thickness (Fig. 83). Others are found which show all degrees of compactness down to the friable, weakly coherent variety which is in common use, and is known as chalk. Marl, or bog lime as it is sometimes called, is still less compact than chalk. The colors of limestones are also variable, but are usually some shade of gray, being at times almost black.

Limestones frequently exhibit the effects of the solvent action of water as shown in caves, often of immense size, and in the appearance of surface outcrops (Fig. 16).

When ordinary limestones are subjected to pressure and heat in the earth's crust they are changed to crystalline limestone, certain varieties of which take a good polish and are used for decorative purposes, being known as marble (Fig. 87). In the process of change the impurities, such as silica and clay, in ordinary limestone, form new combinations and give rise to minerals. One of the most common of these, in crystalline limestone, is the silicate of calcium, known as tremolite, a white amphibole. It may be added that crystalline limestones are, at times, for instance in parts of eastern Ontario and northern New York, veritable storehouses for minerals, and are much sought after by collectors. Among the minerals, some of which frequently occur in well formed crystals, that are commonly found in these rocks may be mentioned amphibole, apatite, calcite, chlorite, corundum, dolomite, feldspar, galena, garnet, graphite, mica, molybdenite, pyrite, pyroxene, quartz, serpentine, sphalerite, talc.

Rocks of Organic Origin.

In addition to limestones there are a few other rocks, not calcareous, which have an organic origin and occur at times in large masses in the earth's crust. The most prominent of these are coal beds. On a preceding page we have shown that coal cannot properly be called a mineral. Coal beds can, however, be classed as rocks of organic origin.

Infusorial earth, or tripolite, a substance which is in common use as a polishing powder, can also be placed in the class of organically formed rocks. It forms beds, similar in appearance to marl or chalk, which are made up of the silicious shells or frustules of minute organisms known as diatoms.

From the remains of animals they contain, many phosphatic rocks are seen to be of organic origin.

Certain large deposits of iron ore, especially limonite, are formed indirectly through organic agencies. Decomposing vegetable-remains give off carbon dioxide and other compounds, which, with water, dissolve iron out of rocks of various kinds, through which it is scattered in small quantities. These iron salts are carried in solution by streams and rivers, or by underground waters, to places where the conditions for the precipitation of the iron are suitable. For example, the waters working over the southern face of the Laurentide hills, in the province of Quebec, dissolve iron out of the rocks, by means of decomposing vegetable and other matter. This iron is carried southward by the streams till a lake or pond is reached. Here, the movement of the water being checked, the soluble iron compounds are oxidized by the air and precipitation of limonite takes place. Such deposits are usually classed as organically formed rocks. Precipitation of iron is sometimes aided by organisms, such as algae.

Chemically Formed Rocks.

Other substances, such as sodium chloride or common salt, calcium sulphate or gypsum, and silica, occur in considerable quantities in solution in some waters, from which they are deposited by direct precipitation. On account of the fact that these substances are precipitated directly from water, and form large masses, they are classed as chemically formed rocks.

The waters of the oceans and seas have undoubtedly always contained salt and gypsum in solution, and new supplies of these substances are constantly being carried seawards by streams and rivers. Salt is found in small quantities in most rocks. Even in those of the igneous class it is frequently seen in small crystals when the rocks are examined microscopically. On the decay of the rocks it goes into solution and most of it finally reaches the ocean. Iron pyrites, and other minerals decomposing, give rise to sulphur compounds which react on limestones and other calcareous materials to form gypsum, which is also carried off by water, although it is much less soluble than salt. By the formation of barriers, through the oscillations which take place in the crust of the earth, or from other causes, arms of the sea are cut off from the main body, and, the water gradually evaporating, gypsum and the less soluble substances are first deposited, and then salt and the more soluble materials. Streams and rivers also carry these substances in solution into lakes, especially those which have no outlets, in arid regions, thus causing in time the formation of concentrated solutions, from which gypsum and other minerals are precipitated.

Many hot springs, such as those in the Yellowstone national park, contain much silica in solution, which, as the temperature and pressure are lowered, is precipitated, and deposited at the surface. Such deposits consist of amorphous silica, which is frequently called sinter. Chert, flint and chalcedony are of similar composition and origin.

C.—METAMORPHIC ROCKS.

For our purpose it is not necessary to add to what has been said on pages 21 and 120, concerning the third great class, known as that of the metamorphic rocks.

ROCK STRUCTURES.

Under this heading we shall briefly describe the forms which are commonly met with in the field and which are most frequently referred to in geological literature.

The illustrations, figs. 75 to 87, represent some of the chief structures found among rocks.

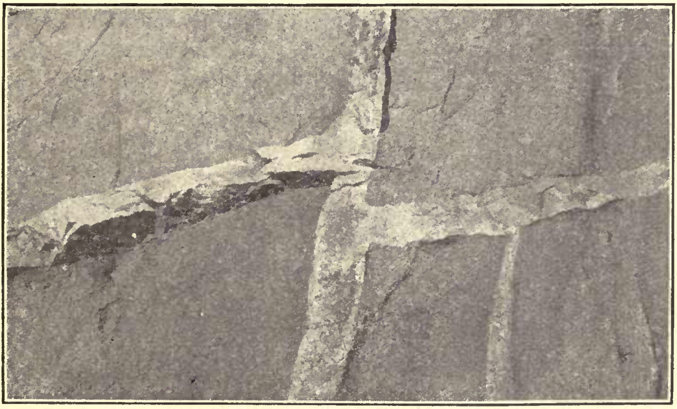

Fig. 75.

Dikes of granite in crystalline limestone. Chandos Township, Peterborough County, Ont. Before the intrusion of the granite there was movement in the walls of one of the cracks, as the two parts of the dike running from right to left do not join. [Dr. A. E. Barlow, G.S.C.]

The forms assumed by those of the igneous class are numerous and depend on the character of the openings made in the earth's crust chiefly through the disturbances to which it is subjected. If molten material pours into a crack or fissure and cools there, the resulting igneous mass is known as a dike (Figs. 63, 75, 76). Frequently igneous material spreads out between the beds of fragmental rocks and on cooling forms a sheet or sill. At times the strata are arched above the igneous intrusion, the latter being more or less dome-shaped and known as a laccolite. Molten matter which issues from a vent in the crust and spreads over the surface is known as a lava flow. The columnar structure, which is commonly seen in basalt flows, is shown in fig. 68. The columns are perpendicular to the cooling surfaces. Columns are at times developed in trap dikes. In this case they extend from wall to wall of the fissure. Small cavities are frequently found on the surface of flows. They are formed by the expansion of gases in the molten mass, and produce the amygdaloidal texture referred to on a preceding page (Fig. 67). The igneous matter which consolidates in the orifice of a volcano is called a neck. Frequently granite and other igneous masses are exposed at the surface in a roughly rounded form which, if of comparatively small size, is known as a boss. If such an exposure occupies a considerable extent of territory and extends to unknown depths in the earth, it is called a batholite.

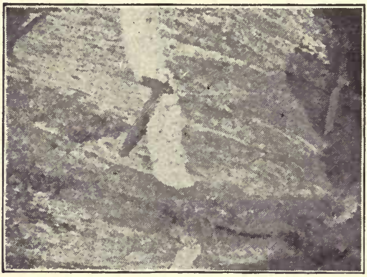

FIG. 76.

Narrow dike of corundum-bearing syenite in gneiss. Township of Carlow, Hastings County, Ont.

Stratification.

Characteristic structures are also found among the fragmental and schistose rocks. Some of these, such as bedding or stratification, which have already been described, depend on the mode of formation, while others are secondary and are due to the shrinkage of the earth's crust through loss of heat, and are chiefly connected with folding and fracturing.

Anticline and Syncline.

Bedding or stratification is the structure most characteristic of the aqueous or fragmental rocks (Figs. 72, 81, 83). We have seen that it is due to the fact that the materials of which these rocks are composed have been deposited and sorted by water. Under normal conditions the beds occupy a horizontal position. When material is deposited in the presence of strong currents or eddies, the structure produced is usually something like that represented in fig. 77, and is known as false or current bedding. Various degrees of folding in beds are seen (Figs. 78, 79). The folds may be gentle, or the bending may be so intense that the strata are squeezed sharply together and broken across the folds. The ridge-like forms, A, in the folds are known as anticlines or anticlinal folds; while the ditch-like depressions, S, are called synclines or synclinal folds. When the surfaces of folds are eroded or worn down the resulting outcrops are, at times, difficult to understand. This will be seen from a study of figs. 64, 78, 79.

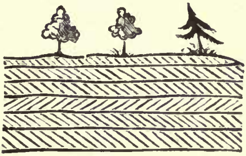
FIG. 77.
Current bedding.

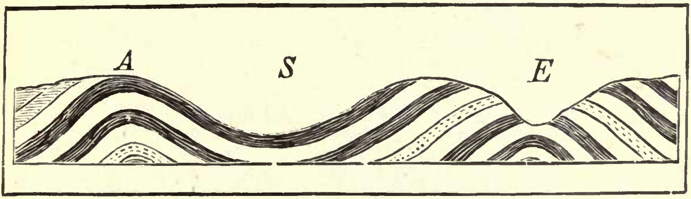

FIG. 78.—*A*, Anticline; *S*, Syncline; *E*, Eroded Anticline.

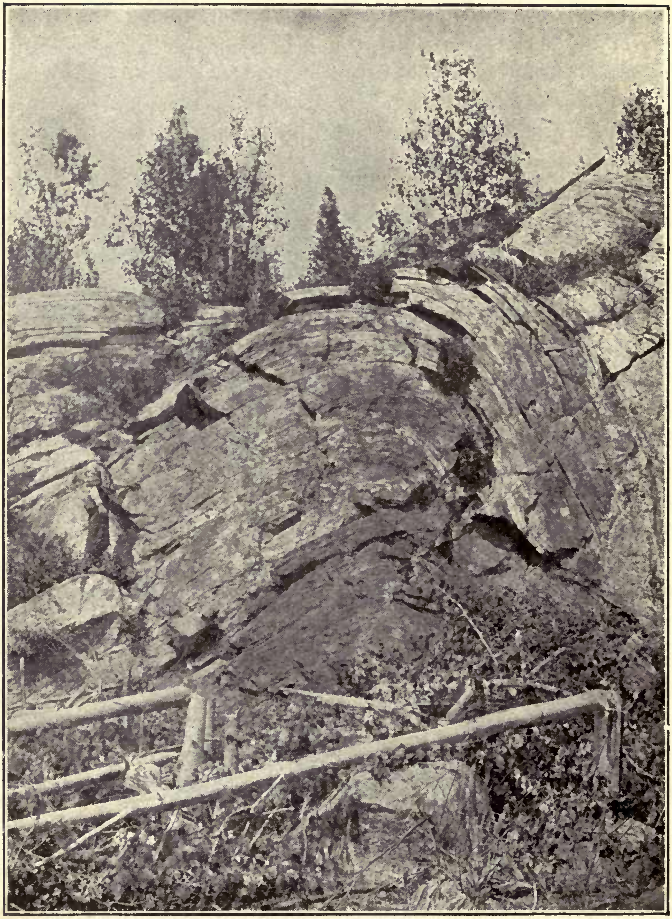

FIG. 79.

Anticline in gneissoid rocks, Township of Lutterworth, Haliburton district, Ont.

[Dr. A. E. BARLOW, G.S.C.]

Faults.

Fracturing of rocks accompanies intense folding, and at times fracturing takes place without folding. Fissures are formed, and, as we have seen, these are in course of time frequently filled, either with mineral matter deposited from solution in water, or by molten matter which cools and consolidates. On the one hand, mineral veins are formed, and on the other, dikes (Figs. 15, 75, 76). When a rock is fractured, there is often a movement of the walls of a fissure so that they no longer match; the part on one side sometimes slips down or is pushed above the other (Figs. 75, 80). Such structures are known as faults. In

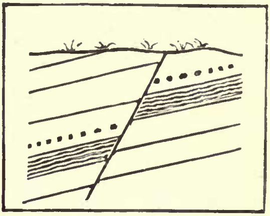

Fig. 80.
Faulted Beds.

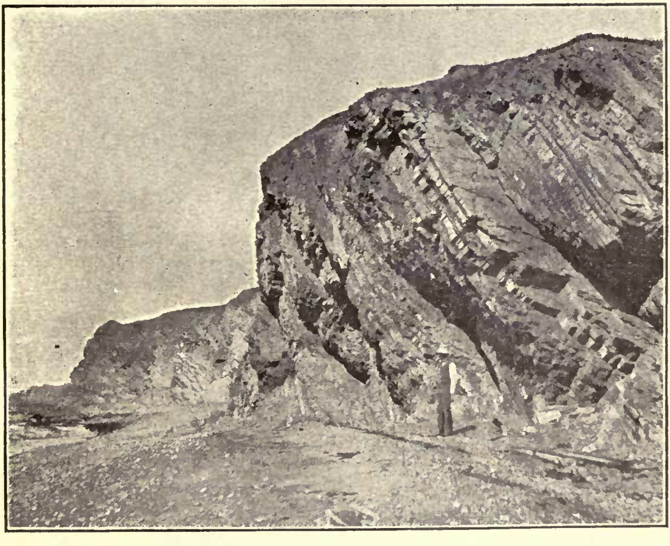

Fig. 81.—Beds of shale which dip at an angle of about 45° from the horizontal. Arisaig coast, Antigonish County, Nova Scotia. [Dr. H. M. Ami, G.S.C.]

fig. 80, the mass of rock on the upper side, or hanging wall, as it is called, of the crack has slipped down. This is the most common kind of faulting, and the structure is known as a normal fault. If the reverse has taken place, the part of the beds on the hanging-wall side has been pushed above that on the lower, or what is known as the foot-wall side. Such a structure is called a reversed fault. It is readily seen that a vein occupying a crack or fissure along a line of faulting is likely to vary in width. In the parts where the walls come together the vein is said to "pinch." Faults are common in veins and in coal beds.

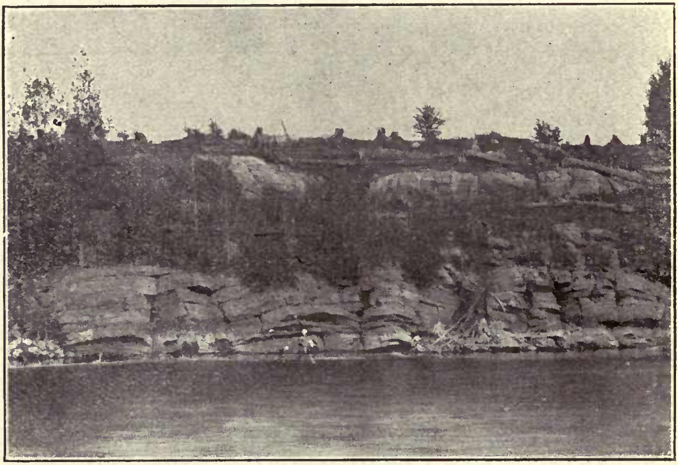

FIG. 82.—Gneissic strata dipping away from a shore. The line of strike is approximately parallel with the shore. Brennan's Creek, near Old Killaloe, Ont.
[Dr. A. E. BARLOW, G.S.C.]

Dip and Strike.

The angle which beds of rock make with a horizontal plane is known as the angle of dip (Figs. 81, 82). If the beds are in a vertical position, for instance, they are said to have a dip of 90°. The beds on the two sides or legs of an anticlinal fold dip away from each other, while in a syncline they dip towards the same line (Figs. 78, 79). The term "strike" is applied to the direction which would be followed by the out-cropping edges of strata on a horizontal plane. The line of strike is always at right angles to the line of dip. In order to see whether he thoroughly understands the terms "dip" and "strike," the reader should experiment with a book. Hold it so that its back rests on the table, and have a compass at hand. In the position you have the book, what is the direction followed by a line parallel with the front edges of the leaves of the book? This corresponds to the strike of the upturned edges of beds of rock. A line drawn at right angles to this across the face of the book is the line of dip. Or the dip is the direction in which water would flow down the face of an inclined stratum. Try to place the book in such a position that it will represent an inclined bed of rock whose strike is north and south, and dip 45° to the west. Figs. 81, 82 illustrate the terms "dip" and "strike." In speaking of directions, contractions are used. The initials N. or S., for north and south respectively, are always given first. These are followed by the number of degrees, and by the initials E. or W., for east and west. For example, if the strike of certain beds is twenty degrees west of north, the direction is written thus:—N. 20° W.; and if ten degrees south of east, it would be written S. 80° E. Only the angle and general direction of the dip need to be recorded if the strike is given, since the dip is at right angles to the strike. Thus, if the strike of the beds is S. 80° E., and they dip 15° in a direction S. 10° W., this would be stated as strike S. 80° E., dip 15° S.

Joints.

All rocks are traversed by divisional planes, or cracks called joints. In sandstones, limestones, and other aqueous rocks, there are usually two sets of joints, which sometimes cross at nearly right angles, and which are often highly inclined to the bedding planes. These rocks are thus divided into blocks of various sizes, the beds forming a third set of parting surfaces. The character of rock scenery depends on jointing to a considerable extent. This is illustrated by fig. 83, which shows cliffs of limestone fashioned by jointing.

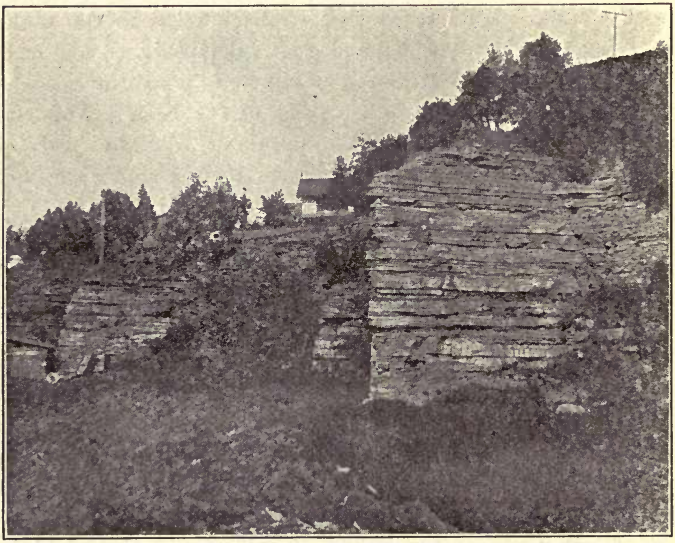

FIG. 83.

Approximately rectangular jointing in beds of horizontally-lying limestone. Queen's wharf, Ottawa, Ont. [Dr. H. M. AMI, G.S.C.]

In quarrying, joints facilitate operations, the rocks separating along the cracks (Figs. 83, 84). Joints are probably due, in most cases, to contraction in rock masses. In aqueous rocks this is brought about by drying, while in those of the igneous class the rocks shrink on cooling. The blocks formed by joints in granite and other igneous rocks are not usually so regular in form as are those in rocks of the aqueous class. There are frequently three systems of joints in igneous rocks.

Slates, which are, as we have seen, metamorphosed clay, separate readily into thin layers, which furnish the material commonly used for roofing purposes. This character of these rocks is known as slaty cleavage. Cleavage is independent of the original bedding, the slate frequently splitting along planes which are, at times, almost at right angles to the beds. This is well brought out in cases where the beds in a slate series are not all of one color. The cleavage structure is produced by pressure, and the plane along which slates split is at right angles to the line along which pressure has been developed.

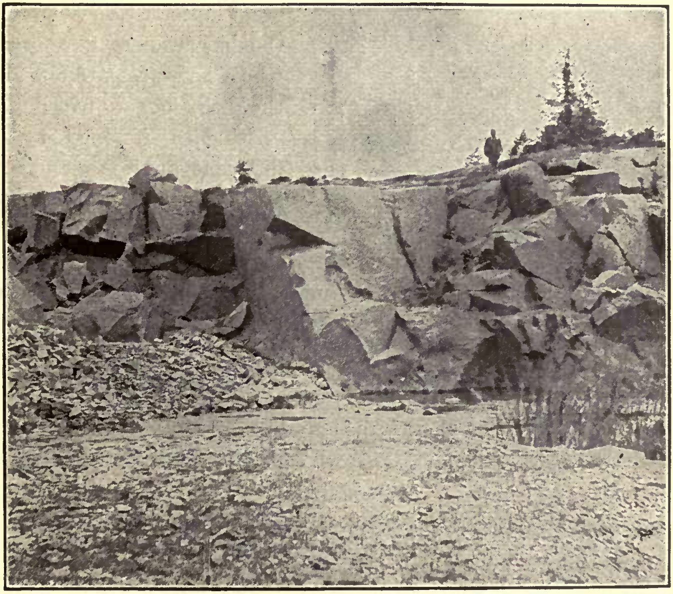

Fig. 84.—Jointing in granite. Barriefield quarry, Kingston, Ont.
[Dr. H. M. Ami, G.S.C.]

AGE OF ROCKS.

In undisturbed aqueous rocks the uppermost beds are, of course, the youngest. Where there is evidence of *unconformity,* shown by the upper surface of the lower series having been eroded, there has been in many cases a great lapse of time between the deposition of two series whose beds are parallel. If the beds of an overlying series are inclined at a different angle to that of an underlying series, we also have evidence of difference in age between the two (Fig. 85). In much disturbed regions older beds are sometimes found over-lying younger ones.

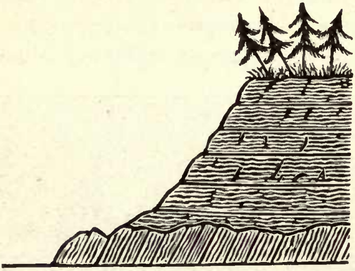

FIG. 85.
Unconformity. Horizontal beds resting on highly-inclined beds.

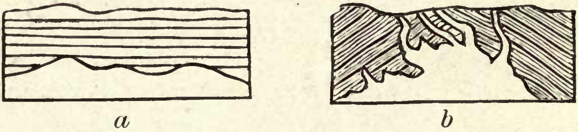

FIG. 86.

a, Horizontal beds lying on eroded surface of massive granite; the beds are therefore younger than the granite. There is a great difference in age between the two series.

b, Granite cutting or intruding disturbed beds; the granite is therefore younger than the beds.

If a dike cuts through or intrudes a series of beds, the dike rock is shown to be younger than that of the beds (Fig. 87). Similarly, if an igneous mass is intruded by a dike, the rock of the latter is the younger of the two. Frequently after dikes or veins have been formed fissuring takes place, and other dikes or veins cut across the previously formed ones

(Fig. 92). While it is not always possible to determine the relative ages of igneous or metamorphic rocks in several isolated outcrops in a district, the ages of such outcrops of aqueous rocks can in most cases be learned. This is owing to the fact that nearly all fragmental beds contain characteristic fossils which, to one versed in paleontology (the study of ancient life-forms), are almost as useful as numbered labels on each bed would be in determining the relative ages of the beds.

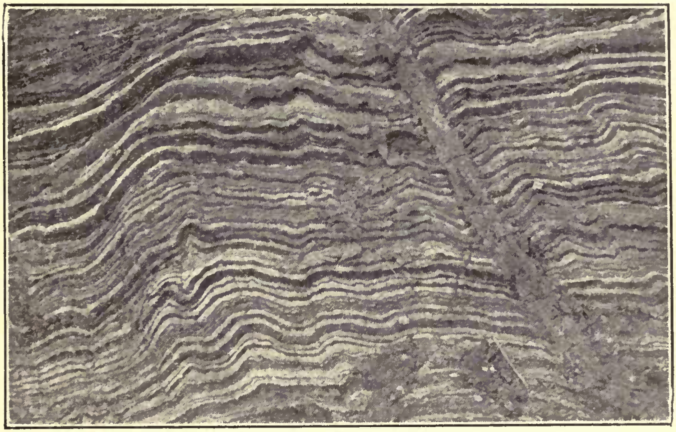

FIG. 87.

Basic dike cutting contorted beds of crystalline limestone, Township of Methuen, Peterborough County, Ont. [Dr. A. E. BARLOW, G.S.C.]

The paleontologist needs to have a knowledge of the various classes of plants and animals, which is only possible to one with a training in botany and zoology. For this reason and on account of the fact that our space is limited, we shall not attempt to give more than a brief outline of the use which is made of fossils in determining the ages of the aqueous rocks. It has been proved by a study of these rocks in many parts of the world that the oldest of them contain fossils which represent lowly organized plants and animals. As we ascend in the scale from the older to the newer, the entombed remains represent, successively, more highly organized forms, the more recent containing remains similar to those of living forms.

On no part of the surface of the earth is there an exposure of strata which embraces aqueous rocks of all ages. In most districts representatives of only a few ages of this class are found. At times, for instance, we find only those of older age. In other cases we find rocks of the middle age of the earth's history only, and so on (Fig. 86*a*). By adding together the different sections of various outcrops over the land surface we come to have a fairly complete geological scale.

AGE DIVISIONS.

The oldest rocks belong to the crystalline series, and embrace representatives of both the igneous and the metamorphic classes. Since the oldest fossiliferous rocks which rest on these are known as the Cambrian (so named from Cambria, an ancient name for Wales, where rocks of this class were first studied), this old crystalline series is called the pre-Cambrian.

PRE-CAMBRIAN.

These pre-Cambrian rocks have been variously subdivided. The names, which are given to the subdivisions in part of northeastern North America, are in descending order, from the younger to the older, as follows:—

Pre-Cambrian.[*]

KEWEENAWAN.
HURONIAN
  Upper.
  Middle.
  Lower.
LAURENTIAN.
KEEWATIN.

The names of these subdivisions have been derived, like Cambrian, from localities in which the rocks were first studied. Keewatin is a place name in northwestern Ontario. Laurentian comes from the Laurentide hills to the north of the St. Lawrence river. Huronian was given on account of the fact that rocks of this class occur on the north shore of Lake Huron. Keweenawan is derived from Keweenaw Point in Michigan.

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[*] The name Archean is sometimes used in place of pre-Cambrian.

The Keewatin, the oldest of the series, is what has been called an igneous complex, consisting largely of greenstones or traps of different ages, together with quartz-porphyry and related types. After this complex had been much disturbed and folded, it was intruded by granite and granitoid-gneiss, to which the name Laurentian is applied. After the intrusion of these granites and gneisses into the Keewatin, erosion took place, and the surface was worn into hills and valleys, much like those which may now be seen in more rocky and barren districts. This period of erosion was of long duration and represents a great interval of time whose length cannot be approximately estimated.

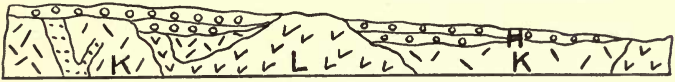

Fig. 87 *bis*.

The Keewatin, K, is the oldest rock shown in the section, as it is cut by the Laurentian granite, L. The Huronian, H, consisting of conglomerate and other fragmental material, is deposited on the eroded surface of the Keewatin and Laurentian.

On this eroded Keewatin and Laurentian surface was deposited a series of fragmental rocks which are known under the name of Lower Huronian. These rocks are made up of water-worn fragments of the Keewatin and Laurentian series, together with, in some localities, volcanic fragmental material. They are also frequently found to have been intruded by dikes and masses of igneous material (Fig. 87 *bis*). Originally, the Lower Huronian undoubtedly consisted largely of gravel, sand, and clay. These materials have since been subjected to great pressure and heat, and are now compact conglomerates, quartzites and slates, together with more or less crystalline limestone. If life existed at this period of the earth's history, all direct evidence of it has been lost. Fossils could not be preserved under the conditions to which the Lower Huronian rocks have been subjected.

While the Middle Huronian rocks, which consist of metamorphosed fragmental material intruded by more or less igneous matter, is unconformable to the Lower Huronian, there was a much shorter period of erosion between the deposition of the latter and the former than there was between the end of the Laurentian period and the beginning of the Lower Huronian.

The Upper Huronian has a similar unconformable relation to the Middle that the latter has to the Lower. The Upper Huronian is at times known as the Animikie series. In the Lake Superior region it consists of slates and other fragmental rocks. Cutting these, or intruded between their beds, there is frequently much trap.

There has been a greater lapse of time between the formation of the Animikie series and the overlying Keweenawan than between any two of the three members of the Huronian. This is shown by the great erosion to which the Animikie rocks have been subjected prior to the deposition of the Keweenawan sediments, and the less amount of disturbance which the latter show.

There is a great development of conglomerates and sandstones in the Keweenawan. During this period there were also great eruptions of trap. This trap now presents some striking features in the topography of the shores of Lake Superior.

In eastern Ontario and in New York and other northeastern States, there is a series of pre-Cambrian crystalline rocks, to which the name Grenville (from the county of that name) is applied. One of the most characteristic members of this series is the crystalline limestones. The relationship of the Grenville to the Huronian and other members of the pre-Cambrian of the Lakes Huron and Superior region has not been determined. These rocks in this lake region have been more carefully studied than has the pre-Cambrian of any other part of North America. While similar assemblages of crystalline rocks are known elsewhere, they cannot, at present, be classified on the same basis as those of the region mentioned.

In the study of the pre-Cambrian, on account of the rocks not containing fossils and being much disturbed, difficulties are met with which are not encountered ordinarily in the post-Cambrian formations. It is hoped, however, that the preceding brief description of the characters and relationship of these rocks will not be found too perplexing by the reader.

Economic Importance of Pre-Cambrian.

The pre-Cambrian system in the Lakes Huron and Superior region, at least, is of far greater economic importance than the more recent formations. In this region these rocks outcrop over a vast territory. In the Keweenawan are found the great native copper deposits of the state of Michigan. In the Upper Huronian or Animikie are the unrivalled iron deposits, soft hematite, of the Mesabi range of Minnesota, and the silver deposits of Thunder Bay. The iron deposits of the Vermilion range of Minnesota, and similar deposits elsewhere in the region, occur in Keewatin rocks. The greatest nickel deposits known, those of Sudbury, Ontario, are also in the pre-Cambrian. It will thus be seen that an acquaintance with the pre-Cambrian system is incumbent on any one who desires a knowledge of general geology. Possessing a knowledge of the system in the region referred to, one will be prepared to do something towards unravelling the intricacies of similar systems with which he may be brought into contact in other parts of the world.

CAMBRIAN AND POST-CAMBRIAN TIME.

The relative ages of the pre-Cambrian rocks are determined, as we have seen, by means of their structural relations. The ages of the Cambrian and later sedimentary formations can usually be learned from their fossil contents. These formations are conveniently divided into three great groups. The fossils in the oldest of these represent more lowly organized plants and animals than do those of the more recent. More and more highly organized forms are found as we pass upwards from the oldest to the youngest.

The following table shows the names which are given to these three groups, the pre-Cambrian forming a fourth, in descending order from the youngest to the oldest, together with the chief subdivisions which are made in each, more especially in the north central part, or the region in the vicinity of the Great Lakes of North America. The reader will see that, counting the Eozoic, the eras are divided broadly into seven ages, depending on the character of the life in each.

Human history is divided into various periods and ages. Thus we speak of the age of Greece and of the Elizabethan epoch. Similarly in geological history there are the divisions which are shown in the table which precedes this paragraph. These are given various names by different authors, but we shall speak of the grander ones, those in the column to the left, as eras or groups. Those in the next column to the right may be called periods or systems, and those in the third column epochs or formations. We have thus, for example, the Paleozoic era, the Devonian period, and the Corniferous epoch. Or we speak of these divisions in a more general way, as rock subdivisions, as group, system and formation respectively.

The groups are given specific names according to the character of the life which existed during the various eras. The lower division of the pre-Cambrian is known as the Azoic

Era or Group.			Period or System.	Epoch or Formation.
CENOZOIC	QUATERNARY	Age of Man	RECENT = Bedded clays, sand, sand dunes, marl deposits, peat bogs, etc.	
			GLACIAL = Boulder clay, moraines, etc.	
	TERTIARY	Age of Mammals	Pliocene. Miocene. Eocene.	
MESOZOIC OR SECONDARY		Age of Reptiles	Cretaceous. Jurassic. Triassic.	
PALEOZOIC OR PRIMARY		Age of Amphibians	Permian.	
			Carboniferous.	Coal measures, etc.
		Age of Fishes	Devonian.	Portage-Chemung. Hamilton. Corniferous. Oriskany.
		Age of Invertebrates	Silurian.*	Lower Helderberg. Onondaga. Guelph. Niagara. Clinton. Medina. Hudson River. Utica. Trenton. Bird's Eye and Black River. Chazy. Calciferous. Potsdam.
			Cambrian.	
PRE-CAMBRIAN	EOZOIC	Dawn of Life	Keweenawan.	
			Huronian.	Upper. Middle. Lower.
	AZOIC	Without Life	LAURENTIAN = Granite and Granitoid-Gneiss.	
			KEEWATIN = Igneous complex.	

*The lower part of the Silurian, to the top of the Hudson River formation, is sometimes called the Ordovician.

era, owing to the belief that the earth did not support life at the time these lower rocks were formed. Eozoic (dawn of life) indicates that it is believed life began at the time the rocks, to which this name is applied, were being formed. The terms Paleozoic (ancient life), Mesozoic (middle life), and Cenozoic (recent life), are self-explanatory. The fossils found in the great groups of rocks to which these names are given are characteristic. While many animals and plants have become extinct since the beginning of the Cenozoic, they do not show such great differences from those now in existence as do the remains found in the Mesozoic. Paleozoic fossils prove that the life of that era was vastly more different from existing forms than are those of the Mesozoic. In the earlier part of the Paleozoic, for instance, all plants were lowly organized and were not represented by land forms, while there were no vertebrate animals then in existence. The animals belonged wholly to what are known as the invertebrates, or those without back-bones. The great group of animals, known as mammals, appeared first in the Mesozoic but belonged to the more lowly organized forms, very few of which are now in existence. The characteristic animals of the Mesozoic were the reptiles which existed in great numbers and many of them were of gigantic size. In the Cenozoic, mammals, the highest group of animals, became predominant, and reptiles then played but a subordinate part in nature. Among plants there have been similar stages of development.

Periods.

The divisions, or periods, in pre-Cambrian time have been explained on a preceding page.

We shall now briefly explain the origin of the names which are given to post-Cambrian periods, or those divisions in the second vertical column in the table.

It is found that certain divisions can be made in the three post-Cambrian groups, which serve a useful purpose in description and for comparison. In some cases these divisions are made owing to unconformities among the rocks or to distinct changes in the fossils between a lower and an upper set of beds. It is not possible, however, to make hard and fast lines in all cases. In some parts of the world there is little, if any, unconformity between the great groups themselves. The Paleozoic may pass almost imperceptibly into the Mesozoic, but in North America there is a distinct break between them. We may compare the groups to chapters, the systems to sections, the formations to pages, and the whole may be called the "great stone book." Frequently pages or sections are absent, while in other cases the record for a considerable period of time is complete.

SYSTEMS AND FORMATIONS.

Owing to the fact that Cambrian and Silurian rocks were first studied in Wales, the names given to them are appropriate, as has already been explained in the case of the former name. The Silures were a tribe which inhabited part of the ancient kingdom. Rocks of the Devonian age are found in Devonshire, and were first correctly described there; hence the name. In the Carboniferous, the great coal fields of Britain, eastern United States, and the maritime provinces of Canada are found. The name is hence appropriate. Permian is derived from Perm, a province in Russia; and the name Triassic refers to the three-fold division of the first rocks of this period that were studied. Jurassic is derived from Jura, the mountains of that name showing developments of these rocks. Cretaceous refers to the fact that the rocks to which this name was originally given were composed of chalk (creta) or limestone. Eocene is the beginning of the newer period; Miocene, middle; and Pliocene, later period.

The names of the epochs or formations shown in the table originate chiefly from place names in New York state, where these rocks were first studied in North America. Similar formations occur in the province of Ontario and in other parts of eastern America, and these names have been applied to them. The formations of the Triassic and upper series to the end of the Tertiary are not named in the table, as they are of less importance in most parts of North America than those given.

Some authors place the Potsdam formation in the Cambrian. The name is derived from a place in New York state. The name Calciferous refers to the fact that this formation is mainly lime-bearing.

The rocks in these formations are essentially as follows:—

The Potsdam is sandstone, either reddish or white in color, or a conglomerate; the Calciferous, Chazy, Bird's Eye and Black River, and Trenton are chiefly limestones; the Utica is composed of shales which are often bituminous; the Hudson River formation also contains considerable shale and more or less calcareous sandstone; the Medina is largely sandstone which is used for building purposes in many districts, the chief public buildings in Toronto being composed of this stone; the Clinton, Niagara, Guelph, Onondaga, and Lower Helderberg are essentially limestones, those of different formations containing variable amounts of magnesia and lime; the Oriskany is a sandstone formation, while the Corniferous contains some very pure limestones associated with others which carry flint nodules and shales; the Hamilton is predominantly a shale formation, but there are certain pure limestone beds; the Portage-Chemung shows typical shales; the Coal measures and other divisions of the Carboniferous are of great economic importance. Interbedded with the coal are usually sandstones, shales, and other rocks, some of which represent the soil on which grew the plants that gave rise to the coal.

The distribution of these formations of the Silurian and Devonian systems immediately north of Lakes Ontario and Erie are shown on the map (Fig. 88). These banded outcrops

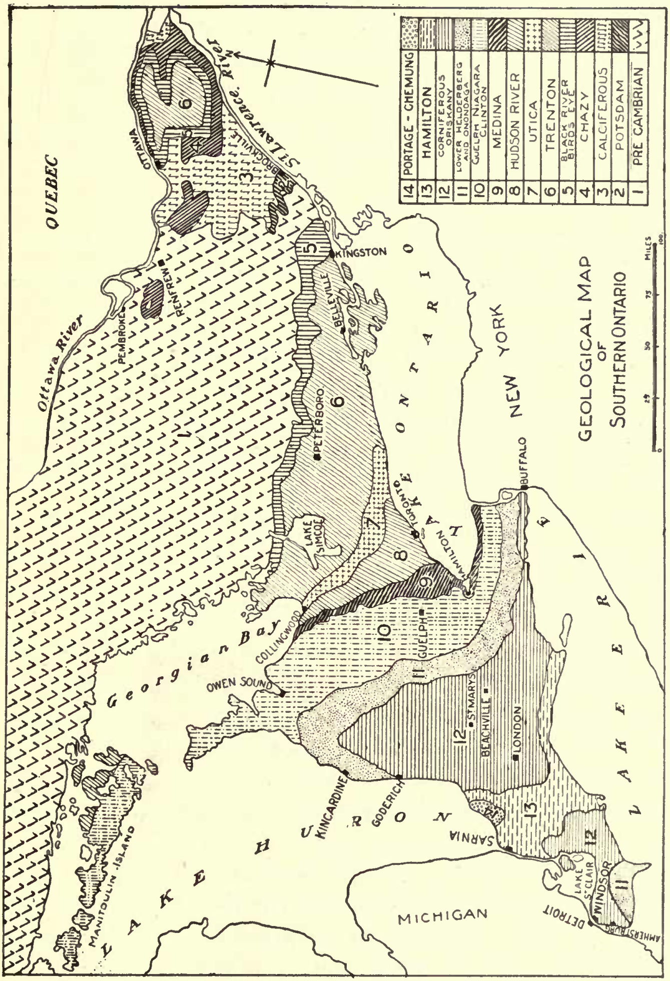
GEOLOGICAL MAP OF SOUTHERN ONTARIO
QUEBEC
Ottawa River
St. Lawrence River
OTTAWA
BROCKVILLE
PEMBROKE
RENFREW
KINGSTON
BELLEVILLE
PETERBORO
LAKE SIMCOE
TORONTO
HAMILTON
BUFFALO
NEW YORK
LAKE ONTARIO
LAKE ERIE
LAKE HURON
Georgian Bay
COLLINGWOOD
OWEN SOUND
GUELPH
ST MARYS
BEACHVILLE
LONDON
KINCARDINE
GODERICH
SARNIA
LAKE ST CLAIR
WINDSOR
DETROIT
AMHERSTBURG
MICHIGAN
MANITOULIN ISLAND
14 PORTAGE - CHEMUNG
13 HAMILTON
12 CORNIFEROUS ORISKANY
11 LOWER HELDERBERG AND ONONDAGA
10 GUELPH NIAGARA CLINTON
9 MEDINA
8 HUDSON RIVER
7 UTICA
6 TRENTON
5 BLACK RIVER BIRDS EYE
4 CHAZY
3 CALCIFEROUS
2 POTSDAM
1 PRE CAMBRIAN
MILES 0 25 50 75 100

FIG. 88.

stretch southward from the Great Lakes and form a similar assemblage in New York state and elsewhere. Of course, it is not intended to give the impression that these rocks outcrop so perfectly at the surface, as the map shows. In many cases they are completely hidden over large areas by a mantle of loose material consisting of clay, sand, and so on, of glacial or recent age.

On a preceding page we have said something concerning the character of a few fossils. We shall now refer to a few of the life-forms of the different systems.

Life.—The life of the Cambrian, judging from the fossils contained in these rocks, although it consisted only of invertebrate animals and marine plants, showed considerable development. We are led to the conclusion that life was in existence during what we have shown in the table as the Eozoic era. The class of trilobites (Fig. 14), for example, in the oldest of the Cambrian rocks are found to be highly organized, and, although this group of animals died out about the beginning of the Carboniferous period, the later forms did not show much greater specialization than did the oldest ones of the Cambrian. Similar conclusions are to be drawn from the character of the fossil brachiopods and other mollusca which were found in the Cambrian (pages 221-6). Some of these were about as highly specialized as their more modern representatives. The plant-remains found in the Cambrian rocks are those of sea weeds or algae, and are sometimes called fucoids. Plant-remains being more delicate than those of the shell-bearing animals, especially, were not preserved in such great numbers. The rocks of the Cambrian contain fossils of other kinds, such as tracks and what have been taken for worm burrows. The most important animals of the period were the trilobites, the rulers during this time.

SILURIAN AND DEVONIAN.

From the bottom of the Silurian to the top, an important development in the life of the period is seen. The dominant forms, during the period, were giant mollusca known as orthoceratites (page 225). These were straight-shell forms, which are represented in existing nature by the coiled nautilus. They had at times a length of several feet, but usually they were only a few inches in length. Their remains are sometimes taken for those of snakes or backbones of fishes. This group of mollusca, known as the cephalopods, to which the orthoceratites belong, is one of the most interesting in connection with the succession of highly organized forms from those lower in the scale. As we have said, those in the lower part of the Silurian were typically straight-shelled. Gradually the forms became more and more coiled, and with more complicated chambers, until the ammonite of the Mesozoic, and later forms such as the nautilus, were developed (Fig. 14).

The Silurian rocks contain a great variety of invertebrate animals, and are hence spoken of as the age of invertebrates. It is not necessary for our purpose to discuss the characteristic types. It may be said, however, that each of the formations in this period, in addition to its distinct lithological character, contains characteristic fossils. The strata of some formations are recognized, for instance, by characteristic trilobites, others by brachiopods, and so forth (pages 211-226).

Towards the end of the Silurian period the great class of vertebrates, or back-boned animals, first made its appearance. The earliest animals of this class were the fishes, which are the most lowly organized among the vertebrates. These early fishes were rather remarkable forms. They were armoured types, being supplied with head-shields and protective plates in many cases. They must have contested for supremacy with the orthoceratites. Fishes did not become predominant, however, until Devonian times, which is often spoken of as the age of fishes. During this period they were numerous, and presented a great variety of forms. Along with the changes which are shown to have taken place among the invertebrates, great progress is exhibited among the vertebrates from Devonian times onward. Older and more lowly forms in both the great divisions of the animal kingdom died out, and are succeeded by those better fitted for the changed conditions.

CARBONIFEROUS AND LATER PERIODS.

In the Carboniferous and Permian, the dominant type of vertebrates was the amphibians, which are represented by the frogs and toads of existing nature. These Carboniferous forms were, however, much larger than existing members of the group. One of the most striking features of Carboniferous times is the vegetation. During Silurian and Devonian times land plants gradually developed, and during the Carboniferous there was a very luxuriant vegetation. The gigantic plants of this period do not belong to the most modern group of plants —that of the dicotyledons—which did not appear till later times. Reptiles begin to appear at the end of the Paleozoic, and become the dominant forms in the Mesozoic. They were represented by a great variety of forms, among which were some gigantic monsters. Reptiles of this period were represented, not only by swimming and land forms, but by flying types as well (Fig. 89). This division of the vertebrates

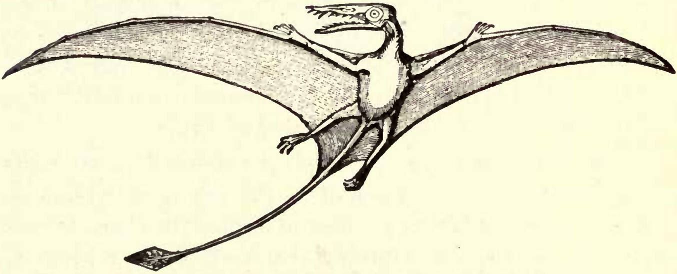

FIG. 89.—A flying reptile of the Jurassic period. (One-seventh natural size).

reached its maximum during this era, and has gradually dwindled since that time. The first birds appear in the Mesozoic, and are related to the reptiles, as the earliest types are teethed forms, showing reptilian characters, and differ much from modern representatives. The mammals, as previously stated, also appeared in the Mesozoic, but they did not make much progress during the era. They were represented by the most lowly organized group of mammals, known as the marsupials, which have living representatives only in Australia. During the Tertiary, the mammals reached great development, and became the dominant types. Plants also made great progress during the Mesozoic and Tertiary times, many fossil forms resembling those now in existence. The mammals of the Tertiary differ from those in existing nature chiefly in their gigantic size. They were represented, for instance, by the recently extinct mammoth and mastodon.

The remains of certain groups of mammals found in these rocks throw interesting light on the succession of types. For instance, remains have been found which show that the first representative of the horse family had five toes. In the lower part of the Eocene, the remains of an animal known as the *eohippus* (dawn horse) have been found. This animal had three toes on the hind foot, and four perfect toes on the fore-foot. On the latter foot there is also a rudimentary fifth toe. In the Middle Eocene is the *orohippus*, with three toes behind and four in front—the fifth or splint being dropped. In the Miocene is the *mesohippus*, with three toes behind and in front, with the fourth toe of the orohippus retained as a useless splint. This is followed by the *miohippus*, more horse-like than the preceding, in which the rudimentary fourth splint is almost gone, and the middle toe or hoof has become larger, the two side toes being still serviceable. Then in the Upper Miocene and Lower Pliocene there is the *protohippus* or hipparion, in which every remnant of the fourth splint is gone; the middle toe has become still larger and the two side hoofs or toes are of little service. In the Pliocene came the *pliohippus*, which is almost a complete horse. It was an animal with one hoof on each foot but the splints, or remnants of the two side toes show its descent. In the Quaternary came the modern horse, *equus*. The hoofs have become rounder, the splint bones shorter, and there are other changes. Instances are not rare where two, more or less functional, toes appear on the horse of to-day, the indication of a reversion to its ancestral type.

It is not known definitely when man first appeared on the earth. His remains have been found with certainty only in recent or what are known as post-glacial deposits. He was probably in existence during glacial times, but we have little proof of this. We have now come, however, in our historical sketch to what is more properly archeology, which in turn passes into what is commonly called history.

PART IV

ECONOMIC NOTES.

Reference has been made on preceding pages to uses of various minerals and rocks. Since economic mineralogy and geology have a very important bearing on the social and industrial fabric, it will be well, in the closing pages of this book, to give a systematic but brief account of them.

Minerals and rocks of economic importance can be divided into the following classes :—

1. Metals and their ores.
2. Grinding and polishing materials (abrasive materials).
3. Materials used to withstand heat (refractory materials).
4. Minerals used as pigments (paint materials).
5. Minerals used for decorative purposes.
6. Minerals used in certain chemical manufactures.
7. Minerals used in agriculture.
8. Fuels and illuminating materials.
9. Materials for brick, pottery, and glass.
10. Stone and cement.
11. Waters.
12. Miscellaneous, *e.g.*, rock salt, etc.

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1. The substances which come under the first of the above classes have been described on preceding pages. An ore is any mineral or rock from which a metal is extracted in economic quantities. Limestone, feldspar and apatite, for example, although they all contain metals, are not classed as ores, since metals are not extracted from them.

We have seen that several metals, notably gold, silver, platinum and copper, are found both in the free or native state and in compounds. The compounds of gold are few in number and of rare occurrence, practically all of this metal being produced from the native material. The same may be said of platinum. A great part of the silver and copper of commerce, on the other hand, comes from compounds. Argentite is an important ore of the former, and chalcopyrite and malachite are ores of the latter.

In the following list the chief ores of the more useful metals are given :—

GOLD.—Native gold in placers and in quartz. Auriferous placers have been extensively worked in Australia, California, British Columbia, the Yukon Territory, and in Alaska. Gold quartz veins are worked in Nova Scotia, Ontario, British Columbia, and in many of the western United States. The metal is also obtained, as shown on a preceding page, from pyrrhotite-chalcopyrite deposits, and from other ores.

SILVER.—Native silver, argentiferous galena and other ores. Argentiferous galena is worked in the western States and in British Columbia. Rich deposits of native silver—associated with smaltite, niccolite and other minerals have recently been found at Cobalt, Ont. The metal is also produced from combination gold-silver, silver-copper, and gold-silver-copper ores.

PLATINUM.—Native platinum in placers. Platinum comes chiefly from the Ural Mountains. A little is derived from the auriferous placers of western North America. The small production of the metal at the nickel mines of Sudbury, Ont., has been mentioned on a preceding page.

COPPER.—Native copper, chalcopyrite, malachite and other ores.

The great native copper mines of the world are those in the vicinity of Houghton, Michigan. Butte, Montana, produces sulphides and other ores of the metal. The third great copper district of North America is in Arizona, where malachite and other ores are worked. Rossland, and other localities in British Columbia, are producers of the metal along with gold. At Sudbury, Ont., the ores carry values in copper as well as in nickel. At both Rossland and Sudbury the copper is extracted from chalcopyrite.

Nickel.—Although there are several rich ores of nickel, such as niccolite, the supply of the metal comes essentially from two localities, Sudbury, Ont., and the island of New Caledonia in the southern Pacific. In the former locality the metal occurs in various compounds, associated in comparatively small amounts with pyrrhotite and chalcopyrite. In New Caledonia the ore is a hydrous silicate of nickel and magnesium.

Iron.—Hematite, magnetite, and limonite are the chief ores of this metal. Spathic iron or siderite, which is a carbonate of the metal, is also worked as an ore.

The largest and most important iron deposits known are those of Minnesota and Michigan. The ore is hematite. Similar ore is mined at Michipicoten on the Canadian side of the lake. Large magnetite deposits occur west of Port Arthur, Ont., and to the north of Sudbury. Magnetite has also been worked in northern New York and in southeastern Ontario at a number of places.

Lead.—Galena is the most important ore of this metal. Since the mineral is frequently argentiferous, much of the lead of commerce is produced in association with silver, as for example in British Columbia and Idaho. One of the great lead districts of the United States is in southeastern Missouri where galena is found in horizontally-lying limestone. The metal is found in economic quantities in several other states and territories. Little lead has been mined in eastern Canada. Deposits have been worked on a small scale in

Frontenac and Hastings counties, Ontario, and on the shore of Lake Temiskaming, Quebec.

TIN.—The ore of this metal is cassiterite. No successful tin mining has been carried on in North America, the commercial supply of the metal coming chiefly from the Straits Settlement and from Cornwall, England.

ZINC.—The most important ore of this metal is zinc blende or sphalerite. An important zinc mining industry is now being developed in British Columbia. In eastern Canada the ore has been mined in a small way in the district east of Port Arthur, and in Frontenac county, Ontario. Rare ores of zinc are worked in the crystalline limestone of New Jersey. Southwestern Missouri possesses one of the most extensive zinc mining industries of the world. The ore here is sphalerite and occurs in more or less irregular deposits in flat-lying limestone.

ALUMINIUM.—While this metal is widely distributed in clays and other rocks and minerals, there is only one ore from which it is extracted on a large scale. This ore is the mineral bauxite, a more or less impure, hydrous oxide of aluminium. Bauxite occurs in more or less loose, earthy deposits resembling somewhat those of bog iron ore. Aluminium is extracted to some extent from the extremely rare mineral cryolite, which is mined only in Greenland.

The reader should review what is said in the descriptions of minerals in Part II concerning the association of ores in deposits. The following are common associations:—Galena and blende with calcite or in limestones, frequently with iron pyrites, barite and other minerals; iron pyrites and copper pyrites; gold and quartz, at times with iron pyrites and mispickel; tinstone in granite, frequently with fluor spar, tourmaline and beryl; cobalt and nickel ores, rarely with native silver; magnetite and hematite with jasper.

Notes on the uses and modes of occurrence of the ores in this list are given in connection with the description of the minerals. The following summary of the modes of occurrence of ores may give the reader a better understanding of this important subject.

ORE DEPOSITS.

A.—SUPERFICIAL OR SURFACE DEPOSITS.

(1) Placers, or stream and shore deposits. We have seen that gold and platinum are found in grains and nuggets in gravel and sand deposits. Cassiterite, the variety known as stream tin, occurs under similar conditions. It has been shown that magnetite is frequently associated in grains with sand along shores.

(2) Bog and lake deposits, *e.g.*, those of limonite or bog iron ore.

B.—STRATIFIED.

(1) Beds of limestone and other rocks contain, at times, a sufficiently high percentage of galena or other mineral to be classed as ores.

C.—UNSTRATIFIED.

1. IRREGULAR.

(*a*) Ores of igneous origin. It is thought that certain deposits of pyrrhotite, magnetite and other ores have originated in the same way as igneous rocks, that is, they have been produced by the cooling of molten material. In some cases the ores occur in large irregular masses, *e.g.*, the nickeliferous pyrrhotite of Sudbury. In other cases the metalliferous minerals are scattered through a mass of igneous rock.

(*b*) Irregularly shaped masses of ore, of aqueous origin, are frequently found at the contact between two series of rocks or occupying caves or caverns.

In addition to the examples represented by *a* and *b* there are other irregularly shaped ore bodies of less interest.

2. REGULAR.

Under this heading come what are properly called veins (*a*) If an ore body occupies an opening which is conformable with the bedding or schistosity of the rocks in which it is found, it is called a bedded or segregated vein. Such veins are usually more or less lenticular in form.

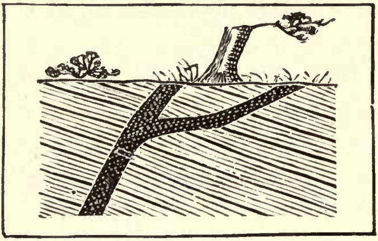


Fig. 90.
Branching vein cutting across strata.

(*b*) If an ore body occupies a fissure which cuts across the bedding or schistosity it is called a fissure vein (Fig. 90). The name is also applied to ore bodies which occupy fissures in massive or igneous rocks. In such a deposit the vein minerals, besides occupying the fissure, may replace to a greater or less extent the neighboring country rock, largely increasing the size of the ore body beyond the walls of the original fissure.

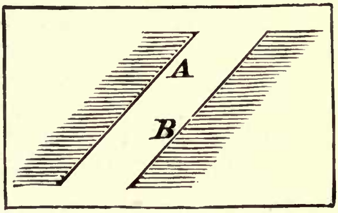


Fig. 91.
A, hanging-wall, B, foot-wall of a vein. The walls may be impregnated with minerals, similar to those in the vein.

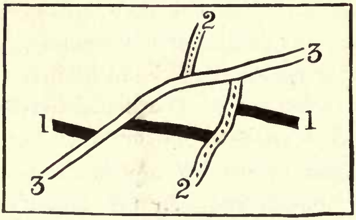


Fig. 92.
Veins of different ages. 1 is faulted by 2, and 3 faults 1 and 2.

We thus see that there are two classes of ore bodies to which the term vein is properly applied. It will also be understood that the use of the term in such an expression as "a vein of coal" is incorrect, since coal occurs in beds.

Reproductions of photographs of fissure veins are shown on pages 24, 62 and 107.

ORIGIN OF DEPOSITS.

The above classification of ore deposits, it will be seen, is based on the shape of the deposits. Another method of classification is based on the mode of origin. Using this system, deposits can be arranged under three headings:—1. Igneous origin. 2. From solution. 3. From suspension.

The reader will have little difficulty in arranging under these three headings the deposits referred to in the classification based on shape. Those of igneous origin are few in number. Deposits formed by the deposition of minerals from solution embrace the majority of ore bodies—*e.g.*, bog and lake deposits; many stratified deposits; many unstratified forms, such as contact and cave deposits, together with segregated and fissure-veins. In discussing the effects of water on rocks, we showed that mineral matter is carried in solution, and deposited when conditions of temperature and pressure change, or precipitating agents are encountered (page 23).

The mineral matter which gives rise to ore deposits is dissolved out of rocks, especially by subterranean, highly-heated, impure waters under pressure. The original source of the ores is the igneous rocks which carry metals or their compounds in small quantities distributed through their masses.

In the third division of the classification according to origin, can be put placers, magnetite sands, and other deposits, the material in which has been carried in suspension by water, and deposited mechanically instead of chemically.

Vein Stones.—In many deposits of aqueous origin the greater part of the mass, especially in veins and in contact and cave deposits, consists of some mineral or minerals which are of no value as ores. Such minerals are known as vein stones or gangue. The two most important of these are quartz and calcite. Barite and fluorite are also common.

Certain ores have characteristic gangues. Gold, for example, in fissure veins or other deposits, is usually associated with quartz, which may fill the whole fissure, the gold being in visible grains or flakes, or invisible. The gangue of lead and zinc ores is frequently calcite.

Value of Deposits.

Since ores are of more interest to most people than are other economic minerals and rocks, it may be well to give a few additional notes, with the object of instructing those who may at some time or other become investors in mines.

The term "mine" is properly applied to an economic mineral deposit only when it has been developed or opened up in such a way as to be capable of being worked as a source of metals or other valuable substances. It is incorrect to speak of a deposit on which no work, or only a limited amount of work, has been done, as a "mine."

Numerous mines in various parts of the world have paid large profits to those who have invested in them. Advantage is frequently taken of this by unscrupulous persons to play on the cupidity of those who have little or no knowledge of the mineral industry. Deposits, from which a few samples of rich ore can be taken, or which may contain no ore that can be worked at a profit, are represented as needing only to be worked to produce great riches. It is well to remember that rich samples are obtainable from many deposits which can never be worked at a profit, and that, in the great majority of districts, the number of deposits which can be worked at a profit are few in number. It should not be concluded that, because one parcel of land contains a rich ore body, others in the immediate neighborhood are as valuable.

Mining is as legitimate as any other industry, but, owing to the ignorance of the public, great frauds are frequently perpetrated in connection with it. There are many capitalists or their representatives that have a thorough knowledge of mining who are constantly looking for promising mineral deposits. It is, therefore, seldom or never necessary to peddle shares in a property of much promise, or which has been proved to be of great value. One should then consider, when he is asked to invest in a mine, whether it is not of doubtful value. Of course some properties, originally of doubtful value, have become dividend-payers; but when investing in an unproved property, a person should not risk more than he is prepared to lose, in case of failure. To possess a thorough knowledge of mines, a man must have gone through as long and as thorough a course of training as do the members of any other profession.

In judging the value of a mineral deposit, many factors have to be considered. Among these may be mentioned: the size of the deposit, amenability of ore to reduction processes, transportation facilities, timber, fuel, labor, and general surroundings.

TERMS USED IN MINING.

There are certain terms used in mining which the reader is likely to meet with in the daily press or in other literature. Some of these will be understood from (Fig. 93), which represents a vertical or highly inclined longitudinal section through a mineral vein which has been developed into a mine. Other deposits in solid rocks are worked in a similar way. Shafts are rectangular openings, frequently, in smaller mines, 7 × 10 feet in cross-section, which are sunk usually in a vertical or highly-inclined position, *s*, fig. 93. From the shaft, usually at intervals of 50 to 100 feet, approximately horizontal openings, known as drifts or levels, are run. These levels enable the miner to work out the ore more cheaply than if he began at the surface and worked the vein downward in the form of a trench. The levels are marked *l* in the diagram. The unshaded portions, marked *t*, connected with the levels and extending above and below them, are called stopes. They are known as overhand and underhand stopes respectively, and represent bodies of ore which have been removed. The diagram shows a shaft-like structure, *w*, sunk below the first level. This is called a winze. A similar opening extending above a level is known as a rise, *r*. An adit is a tunnel run in from a hillside to connect with the workings of a mine (Fig. 94).

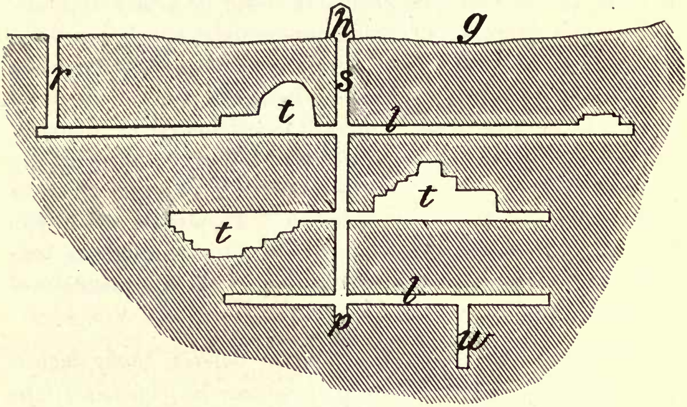


Fig. 93.
Section from the surface (*g*) downward through the workings of a mine. *s*, shaft; *h*, shaft-house; *l*, level; *t*, stope; *w*, winze; *r*, rise. The part of the shaft, in which water is sometimes allowed to collect, below the bottom level, is known as a sump, *p*.

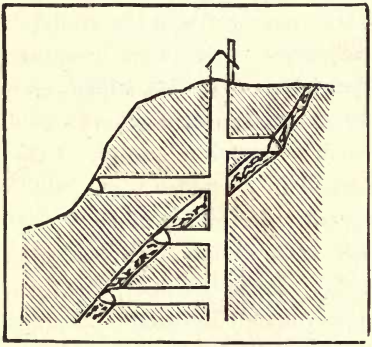


Fig. 94
Shows a vertical shaft sunk on a vein which has a dip of about 45° from the horizontal. An adit connects the shaft with the hillside. Three levels connect the shaft with the vein.

Faults have been described on a preceding page (Figs. 68, 74). It is easily seen that, if faulting has taken place along a fissure which subsequently became a vein, by the deposition of material from solution, the vein will be wider at some points than at others, unless the walls of the fissure were perfect planes. The walls may come together, in which case the vein disappears or is said to pinch. In such a case faulting is frequently indicated by striations, known as slickensides, on the walls of the vein. Such striations are produced by the walls rubbing against each other when faulting takes place.

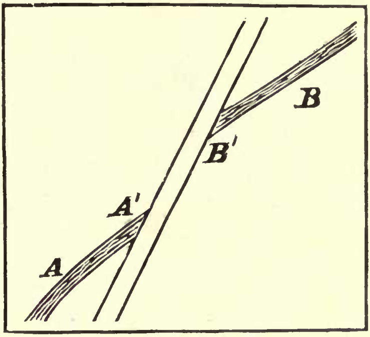


FIG. 95
The vein *A B* is faulted between *A'* and *B'*. If the part *B B'*, on the foot-wall side, is worked from the surface down to the fault, the continuation of the vein, *A A'*, is to be looked for, in the case of normal faults, downward.

In the case where a vein or bed has been faulted it becomes of importance after working to the line of fault to know where to look for the continuation of the vein (Fig. 95). If we suppose the vein has been worked from the surface down to the fault line we see that its continuation is downward, or on the down throw side. Models should be made use of in studying faults. Take a block of wood and mark on it a bed or vein, such as *A A*, *B B*, *E E*, in Fig. 96, and a fault line *F F*. Then saw the block along the line *F F*, and note the effect produced in the vein when one part of the model is sunk a little below the other. Make other models with veins or beds and fault lines placed in various positions.

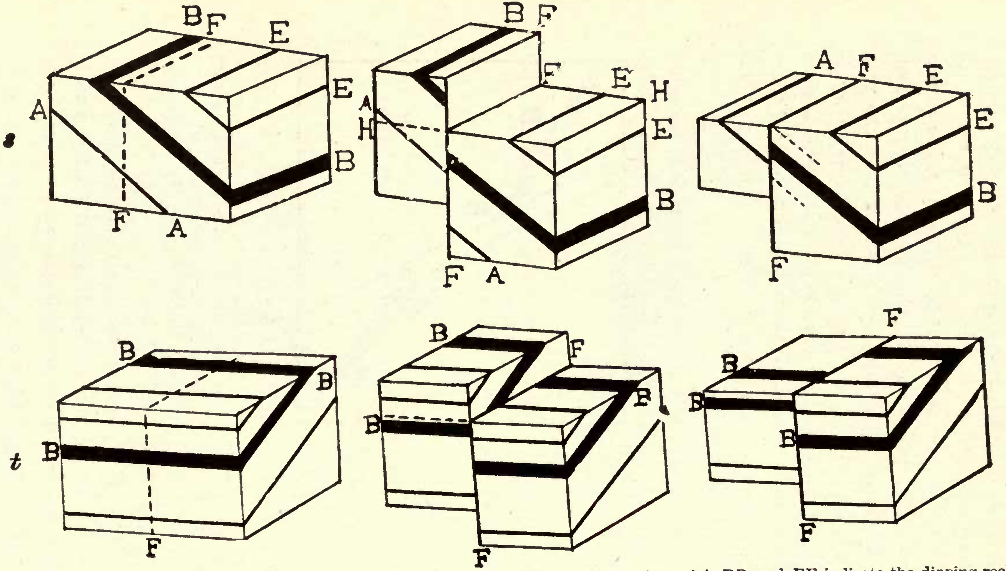


FIG. 96.—Fig. *s* illustrating a strike, and Fig. *t* a dip fault. FF is the fault plane, AA, BB, and EE indicate the dipping rock layers. In the former figure the fault plane cuts the surface parallel to the strike, causing a strike fault, in the latter the strike is cut at right angles, producing a dip fault. On the left the unfaulted block is shown, with the position of the fault dotted. In the centre the conditions prevailing shortly after completion of the faulting are shown, the downthrow block on the right, and with the prominent fault scarp. On the right the conditions prevailing after sufficient time has elapsed for wearing away the upthrow block down to the level of the other side, or rather for wearing the two sides down to a uniform level, are indicated, this being approximately the condition of most of the faults of the region at the present time. In the strike fault this results in the entire disappearance from the surface of the stratum BB, in the vicinity of the fault, the actual thickness of rock so disappearing being comprised in the space between the dotted lines on either side of BB. By varying the amounts of hade and dip, or their directions, repetition of strata at the surface, instead of disappearance, may result. In the dip fault the effect is to shift the outcrop of a given stratum, so that in an old fault, the surface having been worn down, the ends are shifted forward or back, as the case may be, on opposite sides of the fault, as BB is shifted in the diagram. The amount of this shifting increases with increased throw of the fault, and diminishes with increased dip of the rocks. Few faults meet these conditions of correspondence with dip or strike direction exactly, but many make such slight angles with these directions that they are practically fulfilled. (After Prof. H. P. CUSHING. Bulletin 95, N.Y. State Museum.)

Veins sometimes show a banded structure (Fig. 97). This is generally due to the character of the mineral-bearing solutions having changed from time to time as the filling of the fissure progressed. Next the walls there may be bands of lead ore, succeeded towards the centre of the fissure by zinc ore or other kinds. Banding is sometimes produced by the splitting open of a vein and the filling of the fissure thus formed with material different in character from that originally in the vein.

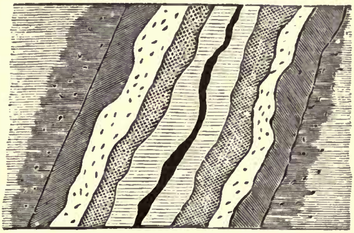


FIG. 97.
Banded Vein.

It is believed that the minerals in veins have in most cases been deposited from ascending waters which were hot and usually alkaline.

2.—ABRASIVE MATERIALS.

In the second class, or that which embraces those minerals and rocks which are used for grinding and polishing purposes, there are a number of well known substances. In commerce these are generally grouped under the name of abrasive materials.

Among the rocks which are used for these purposes are sandstones, which contain angular fragments of quartz firmly cemented together, represented by the ordinary grindstone or scythe-stone. Silicious rocks were formerly used in grist-mills for grinding purposes, but these have now been replaced by the more modern rollers. Fine-grained sandstones, garnetiferous mica-schist, and other rocks are used in the manufacture of whetstones. Tripolite, or infusorial earth, and pumice are used in polishing.

The minerals employed for these purposes include crushed quartz or sand, which is used in polishing marble and other substances; garnet in the form of grains, which is used in the manufacture of sandpaper, and so on; emery, corundum and the diamond. We have shown on a preceding page that grains of corundum or emery are commonly cemented together and moulded into wheels. The reader has, no doubt, seen emery wheels. Whetstones and other grinding or sharpening tools are now also made from grain corundum and emery. The dark or poorly colored varieties of the diamond are employed for abrasive purposes. Its powder is used in polishing the diamond itself; the stones are used for cutting glass, and are set in the bits or cutting parts of the so-called diamond drills with which holes are bored into the solid rock.

Artificial materials are now employed to some extent for abrasive purposes. These include crushed steel, artificial corundum, and the well-known material carborundum, which is manufactured in electric furnaces at Niagara Falls.

Corundum is the most valuable of all abrasives, its applications being wider than those of any other material used for similar purposes. It is hard and possesses cleavage or parting planes, through the effect of which new surfaces are constantly presented as the mineral wears away. The great corundum producing district of the world is in the eastern part of the province of Ontario (page 81).

3.—REFRACTORY MATERIALS.

The materials which are used to withstand heat, or which possess what are known as refractory properties, include the following:—Asbestos, graphite, mica, magnesite, fire clay, certain sandstones, and others.

Asbestos.—The unique mineral, asbestos, sometimes called mineral wool, can be spun or woven, and is commonly made into cloth which is employed in the manufacture of theatre drop-curtains, firemen's clothing, indestructible mail-bags, and other materials which are required to withstand heat. The mineral in a cruder form is used for packing around steam-pipes, to keep in the heat. The refractory character of asbestos was known to the ancients. It is said that bodies were wrapped in asbestos cloth before being placed on funeral pyres, and that the emperor Charlemagne had a table-cloth made of asbestos. The asbestos of commerce is the fibrous variety of the mineral, serpentine. The world's supply now comes practically from that part of the province of Quebec which lies between the St. Lawrence River and the United States boundary (page 99).

Graphite.—The refractory character of graphite has been referred to in the description of this mineral. It was shown that, on account of its not being affected by the heat of ordinary furnaces, and owing to the fact that the mineral is not acted on by molten material, it is commonly used as a furnace lining. Crucibles are frequently made of it.

The mineral occurs in metamorphic rocks, being frequently associated with crystalline limestone. Attention has been drawn to the fact that graphite is in some cases a metamorphosed coal. In other cases, especially in the older rocks, the mineral probably represents the metamorphism of the heavier non-volatile part of mineral oil or petroleum, as vegetation during these early periods had not reached a high enough state of development to produce coal. It is believed by some authorities that mineral oil is of inorganic origin. Hence we can understand that it may have been in as large quantities in the earth's crust during early periods as in later times (page 55).

Mica.—Mica is another mineral which is not easily affected by heat. While the greater part of the mineral which comes into commerce is used for insulating purposes in connection with electrical machines, a certain amount of it, of less pure quality, or what is known as scrap, is employed for covering boilers and for similar purposes. It is also used in stove fronts. Ground mica finds various applications in the arts (page 88).

Magnesite.—Magnesite, when made into bricks, is found to possess highly refractory properties and is now largely employed as a lining in electrical furnaces. Most of this material comes from Greece (page 87).

Fire Clay.—Fire clay is a clay which approaches kaolin in composition, being much purer than the ordinary varieties of clay. The presence of the alkalies, alkaline earths or iron in clays causes them to fuse at lower temperatures than purer clay. The origin of fire clays has been briefly described on a preceding page. It has been shown that they are commonly associated with the coal measures, and are less frequently found in other localities.

Sandstone.—Sandstone, which is composed of pure quartz grains, possesses the property of withstanding high temperatures and is used for linings of furnaces and so forth.

One of the most difficult materials to fuse, or, in other words, one of the most refractory, is quicklime. Pencils of it are used in the oxy-hydrogen light.

Although the minerals and rocks just mentioned are refractory or infusible under ordinary conditions, it may be added that at sufficiently high temperatures most of them are fusible. Even lime has been caused to boil in the modern electric furnace.

If refractory materials are brought into contact with substances for which they have chemical affinity they will fuse with them at a comparatively low temperature. Thus lime in the presence of silica fuses readily.

4.—PAINT MATERIALS.

Minerals from which pigments or paint materials are derived are numerous. Common white paints are usually compounds of lead or zinc, either the oxides or carbonates. The red paints which are used for the commoner purposes are frequently oxides of iron. In some cases hematite or limonite, after being ground and simply mixed with oil, is used as paint. In other cases artificial iron oxide is employed. Different colored paints are produced from arsenic. Many carriage paints are compounds of this metal. The mineral from which arsenic is obtained, as has already been stated, is chiefly mispickel. The mineral barite, when occurring pure enough, is ground and employed as a pigment. It is sometimes used to adulterate the more valuable lead compounds, but for some purposes it has an advantage over other white pigments owing to the fact that it is not acted on by acid fumes. The use of graphite in paints has been mentioned on a preceding page.

Closely associated with paint materials are substances used for staining glass or coloring pottery, porcelain, and other materials. The color of the higher grades of blue glass, for instance, is due to cobalt. Other glasses owe their color to various metals.

5.—DECORATIVE MATERIALS.

Minerals used for decorative purposes include those used in jewelry, and so on. The term stone is generally applied to specimens of minerals which are adapted for use in jewelry. They are called in a general way gemstones, this use of the term being different from the ordinary, the name stone usually being applied to comparatively small, loose, pieces of rock.

Among the most highly-prized gemstones are the diamond and the well-colored and transparent varieties of the mineral corundum, known as sapphire and ruby. The emerald and aquamarine are gem varieties of beryl. Clear, transparent, and flawless varieties of other minerals are commonly cut and used in jewelry. Among these are green tourmaline, garnet, varieties of quartz, feldspar, and many others. All these minerals have been previously described.

In addition to their use in jewelry, minerals and rocks are employed for decorative purposes in other ways. Among these are marble, agate, onyx and other well-colored materials. The stone used in many buildings is frequently selected on account of its decorative character. Some stones are fashionable or popular in certain districts, while others are in demand elsewhere.

6.—CHEMICAL MANUFACTURE.

The minerals which are used in certain chemical manufactures are numerous. Two of the most important, among these, are iron pyrites and sulphur, which are employed in the manufacture of sulphuric acid. Others which may be mentioned are bauxite and clay, which are used in the production of aluminium sulphate and alum. There are many in addition to these, but they come under other headings as well as that of chemical manufacture.

7.—MINERAL FERTILIZERS.

Minerals used in agriculture are somewhat numerous. One of the most important of them is the mineral apatite, which, when treated with sulphuric acid, produces a soluble phosphate that possesses very valuable properties as a plant food. Other phosphates similar in composition to apatite are employed for a like purpose. Calcined gypsum is frequently used as a fertilizer, being then known as land plaster. Lime has beneficial effects on some soils. It tends to make those of a heavy character more easily worked, promotes drainage and supplies a constituent for plant food which is lacking in some soils. The value of lime as a fertilizer is becoming better recognized.

One of the most necessary elements for plant food is potash. A number of minerals supply it. The greatest amount of the potassium compounds in commerce is derived from the salt deposits of Stassfurt, Germany. These waters in addition to common salt carry various salts of potash and other materials in solution. Numerous attempts have been made to invent a cheap process for extracting potash from feldspar, but up to the present success has not been achieved. The fragments of feldspar found in many soils tend gradually to decay and thus supply potash to the plants. Green sand, or, as it is commonly called, glauconite, is a silicate of potash and iron, and is sometimes used as a fertilizer. Common salt is also employed.

Plants gradually abstract the phosphorus, potash, and other substances which serve as their food, from the soils on which they are grown. If the plants are allowed to decay where they have grown the elements are given back to the soil. But when wheat, corn, and other crops are removed from year to year the soil becomes in time impoverished. Hence fertilizers such as those named above should be used.

All soil, as we have seen, results from the breaking-down of compact rocks. Through the mechanical action of water the various fine particles produced may be sorted in such a way that in one locality the surface is covered with a soil which is composed essentially of quartz grains, or what is called sand. In another it may be a stiff clay. While in a third locality the surface soil may be a mixture of sand and clay, or of sand and limestone in a state of fine division.

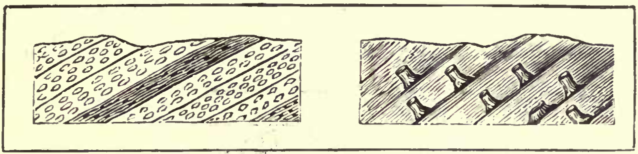
Mixed soils are the most productive since they contain a greater variety of the elements of plant food and their physical character is also important in connection with the retention of moisture or in relation to drainage. Ordinary sand containing little but silica is an unproductive soil; while clays, more or less impure, contain particles of minerals which gradually give up phosphorus, potash, and other substances to growing plants. It has been shown that the mineral apatite, or "phosphate," is present in most igneous rocks. Since all soil and other fragmental rocks are derived from these, it is seen where the plants get their phosphorus.

Phosphorus and nitrogen are found in buds and shoots and afterwards in the seed of plants. Calcium phosphate is an important constituent of the bones of animals. Bones, as the reader probably knows, are ground and used as a fertilizer. It is thus not difficult, as will be seen from what we have said, to trace the source of the phosphorus in bones, through seeds of plants and the soil, back to the igneous rocks. Other substances give stiffness to the stalks and trunks of plants. Silica, for example, is found in comparatively large amounts in what is known as the "scouring rush." Wood ashes, since they contain potash or "lye," are valuable fertilisers. Organic matter is also important.

We have shown that the soils of northern countries consist essentially of material which has been transported for a considerable distance by glaciers, and has been more or less re-sorted by water (Figs. 5, 6). In southern countries, on the other hand, the soil represents the decay of the underlying compact or "bed rock" of the district in which it is found. In certain limestone districts, as for example that of the "blue grass" region of Kentucky, the soil is fertile, while in others where the bed rock is sandstone it is barren. Pure limestones, or those containing little argillaceous or clayey matter, on their decay do not, of course, give rise to soil, the calcium carbonate being gradually carried away in solution. They, like sandstones, are frequently found out-cropping at the surface in agriculturally barren regions.

8.—FUELS AND ILLUMINATING MATERIALS.

Fuels and illuminating materials have been described in connection with minerals. They embrace the various coals, rock oil or petroleum, and natural gas. It is not necessary to add to their description here, but attention may be again drawn to their distribution in North America. The great coal-fields of Pennsylvania and of the Maritime provinces belong to the Carboniferous formation; while those of the western States and western Canada are of Mesozoic age. It



a FIG. 98. *b*

a. The darker layer may be considered to be a coal seam which is dipping at an angle of about 30° from the horizontal.

b. Stumps and trunks of trees are frequently found in coal-bearing strata.

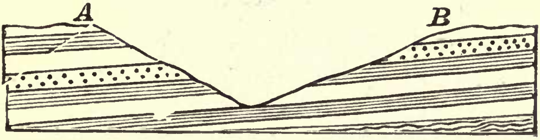


FIG. 99.

Coal seams frequently outcrop along the sides of valleys, A B, which have been cut out by streams or rivers.

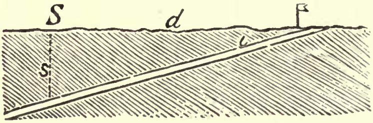


FIG. 100.

If a bed of coal or other substance, or a vein, dips at a certain angle, *i*, it is easy to determine to what depth a shaft, *S*, will have to be sunk from any point at the surface to reach the bed or vein. In the diagram the angle of dip, *i*, and the distance of the shaft, *S*, from the outcrop being known, construct a right angled triangle with angle *i*, and side, *d*, and determine *s*.

has been shown on preceding pages that vegetation, as regards land plants, did not develop greatly until the Carboniferous period. During the Devonian and earlier periods, vegetation was too sparse to give rise to coal deposits. Hence if we know that a certain territory like that of the province of Ontario, to the north of the Great Lakes, possesses no rocks younger in age than the Devonian, except glacial and recent formations, we can conclude at once that such a territory is not coal-bearing. Much capital has been wasted in searching for coal deposits in districts in which geologists know it is impossible to discover them.

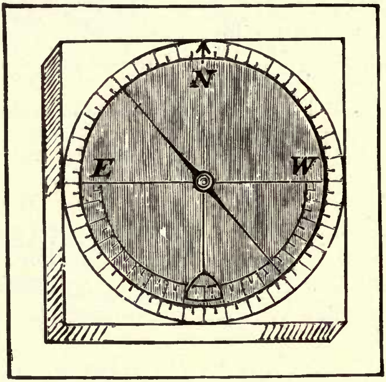


FIG. 101.

Compass-clinometer for determining dip of strata. The clinometer attachment consists, as shown in the figure, of a movable index which hangs freely from the centre of the compass and plays around a graduated arc. Where the upper edge of the compass is held horizontally, the index cuts the zero point of the graduated arc. From each side of this point, the graduation is carried up to 90°. If, consequently, the upper edge of the instrument be placed parallel with the inclined beds of any strata, the angle of dip will at once be shown by the index. [After CHAPMAN].

Some of the thickest coal seams known are found in Nova Scotia. The coal here is the bituminous variety. Two important fields are those of Pictou and Sydney. In western Canada, in the foothills of the Rockies and in the plains to the eastward, coal is found over a vast territory. Near the foothills the coal is of better quality, approaching the bituminous variety more closely in composition than that of the plains, which is lignite. The principal mines are at Lethbridge, Canmore, Anthracite, Frank and Coalfields. The local trade is supplied by small mines at Estevan, Medicine Hat, Edmonton and elsewhere. In British Columbia there is an important coal industry at the Crow's Nest Pass and on Vancouver island – Nanaimo, Comox,—the variety in both cases being bituminous and occurring in Cretaceous rocks. On Queen Charlotte island, anthracite as well as bituminous coal is found.

9.—BRICKS, POTTERY AND GLASS.

Materials for brick, pottery and glass are of common occurrence. The manufacture of bricks from clay has been mentioned, and it has been shown why some possess different colors from others. There are various grades of pottery, some of which require clays of special character. Cruder forms of pottery are frequently made from ordinary brick clays.

In addition to clay, the more compact form of the rock known as shale is frequently employed in the manufacture of bricks and other materials. In the vicinity of the Great Lakes, for instance, shales of the Hudson River formation and of the Medina, together with glacial, inter-glacial, and post-glacial clays, are employed. The reader visiting a deposit from which material is taken for the manufacture of brick or pottery, should try to determine to which of these classes the material belongs. In the manufacture of ordinary glass, the substances made use of are chiefly quartz in the form of sand and pure lime—that is, lime which is composed essentially of calcium oxide. Sand is usually too impure to be used in the manufacture of colorless glass, and it is frequently necessary to bring the material a considerable distance. The crushing of pure quartz often costs too much for glass-making material. Limestones pure enough for glass-making are found among rocks of various ages.

10.—STONE AND CEMENT.

Under the heading of stone and cement materials a large number of rocks are included.

For building structures such as houses, the most common kinds of stone employed are limestone, sandstone, and granite. Slate finds employment as a roofing material. Heretofore blocks of stone of large size have been used in structures such as canal locks. During later years stone has been replaced to a large extent by concrete, which is composed of crushed stone and cement. The term "road metal" is applied to crushed stone employed in the construction of roads.

In addition to the use of stone for structural purposes, we have the use as decorative material. Crystalline limestone, which takes a good polish, is known as marble. It is largely used for the decoration of the interior of buildings. Marble, granite, and other rocks are also used for monuments. Jasper, agate, and other materials are employed for decorative purposes.

Cements can roughly be divided into two classes: (1) Natural or rock cement; (2) Portland Cement. Natural rock cement is produced from argillaceous limestones. When burned, certain of these rocks possess the power of setting or hardening under water. Portland cement possesses properties similar to natural cement but is of more definite chemical composition. It is usually made by mixing marl or powdered limestone, that is practically free from magnesia, with clay and sintering or partly fusing the mixture. The sintered material is ground and comes on the market in the form of a fine powder. Cement is replacing lime to a large extent in building operations. We have already referred to the latter substance, but it may be added that limestones of various compositions are burned in the production of lime. Magnesian limes set more slowly, and are thus better adapted to certain purposes than pure calcareous limes. The pitting which takes place at times in plaster on walls is due to the imperfect slaking of lime. Lime is usually slaked, as no doubt the reader has observed, in shallow boxes or troughs with water. It is best to slake the lime some time before it is used.

Most lime tends to take up carbon dioxide and water when exposed to the air and thus loses its value for use in mortar. Instead of being what is called quicklime, it is said to be air-slaked lime.

The white efflorescence or coating, which frequently appears on bricks, after they have been laid in a wall, is due to the formation of alkaline sulphates. They are soluble compounds and moisture brings them gradually to the surface of the brick-work. The sulphates may be produced by the oxidation of sulphides, such as iron pyrites, present in some clays and limestones; or if coal is used as a fuel, the sulphur may come from it. In order to avoid the disfigurement of walls, materials containing compounds of sulphur, should not be employed in the manufacture of lime or bricks. A little carbonate or chloride of barium added to bricks before they are burned will prevent the efflorescence, if it is due to sulphates in the bricks.

11.—WATERS.

Waters of various kinds are probably of more economic importance, in so far as the great majority of the population of any country is concerned, than is any other mineral or rock.

Waters may be divided into various classes according to their composition. For instance, ordinary drinking water contains only small amounts of mineral matter in solution. There are other waters which contain a great deal of dissolved mineral matter. Many of these waters are of value from the medicinal point of view for either internal or external use. These waters can be sub-divided into several classes. We have, for instance, waters in which the dissolved material is chiefly chlorides; others in which the material is salts of iron, hence called chalybeate waters; others in which there is more or less sulphate or sulphuretted hydrogen present, known as sulphur waters.

Waters frequently become contaminated through imperfect drainage. It becomes of importance, therefore, to know something of the underground structure of any district. Fig. 102 shows how polluted water containing organic matter may drain into a well or spring and thus bring about infection.

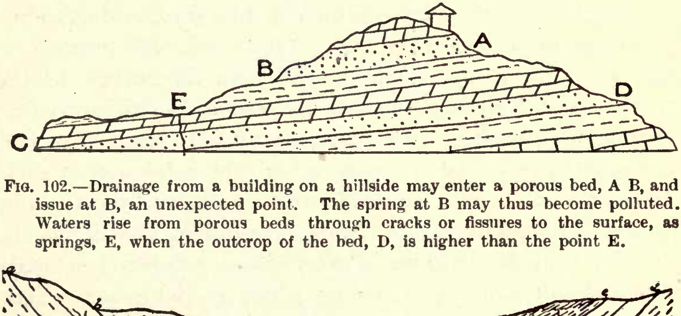


Fig. 102.—Drainage from a building on a hillside may enter a porous bed, A B, and issue at B, an unexpected point. The spring at B may thus become polluted. Waters rise from porous beds through cracks or fissures to the surface, as springs, E, when the outcrop of the bed, D, is higher than the point E.

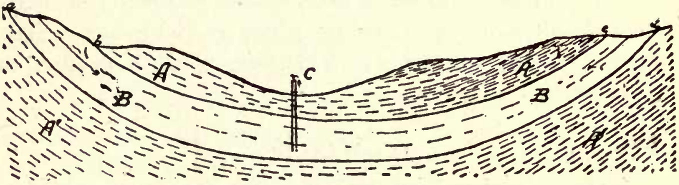


Fig. 103.—If a hole, *C*, is drilled through an impervious layer, *A A*, into a porous bed, *B B*, which is underlain by an impervious bed, *A' A'*, water entering *B B* at the surface, *a b*, *c d*, will rise through the drill hole, *C*, to the approximate level of *a b*, *c d*. [After Dr. F. D. Adams.]

Fig. 102 shows how springs originate, and Fig. 103 shows the reason why water in artesian wells, so called from Artois in France, rises towards the surface or spouts above it at times.

12.—MISCELLANEOUS ECONOMIC MINERALS.

Under the above headings a number of important economic minerals and rocks have not been mentioned. We shall now refer to a few of them under the heading of miscellaneous materials.

One of the most important of these is the substance known as rock salt or halite. Most salt, as we have seen from the description of minerals, is produced by the evaporation of saline waters or brines. At times, however, salt is mined in the solid form. There are frequently great beds of rock salt in association with the Paleozoic and other strata.

Borax and soda (sodium carbonate) are found dissolved in certain lakes in the west, and are obtained by evaporating the water.

Nitre or saltpetre occurs mostly in surface deposits in arid regions. It is also obtained from some waters.

The modes of occurrence and uses of talc, fluor spar, sulphur, lithographic stone, moulding sand and other economic minerals and rocks have been referred to on foregoing pages.

There are uses of certain minerals in addition to those mentioned in the above divisions.

APPENDIX I

CHEMICAL AND BLOWPIPE TESTS.

Most of the minerals which we have described can be determined by the physical characters summarized on preceding pages. It will be well, however, to add here certain chemical and blowpipe tests which can be made use of when the necessary apparatus and reagents are at hand. By their use we shall gain a more perfect knowledge of these minerals, and shall have the means of assisting in the determination of others in which we may be interested. Details should be sought in larger text-books.

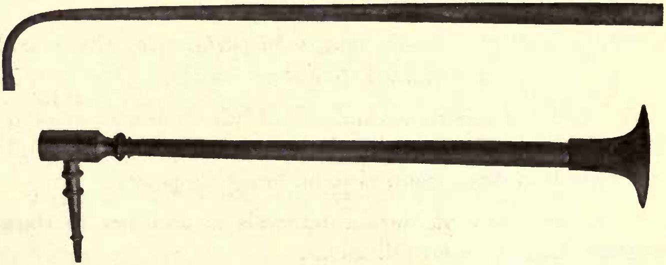


FIG. 104.

BLOWPIPES. The upper one is simply constructed and has a straight mouth-piece. The lower one has a bell-shaped mouth-piece, and consists of several parts screwed together. (A little over one-third natural size.)

The Mouth Blowpipe.—This instrument is in common use in chemical laboratories and by jewelers and other workers. It is inexpensive and simply constructed (Fig. 104). Facility in its more simple uses will be gained with little practice. More can be learned from a few minutes' practice with the blowpipe than from reading several pages describing the methods of using it.

The beginner will probably find the straight mouth-piece easier to use than the bell shaped form.

It is necessary, in some experiments, to keep up a practically continuous blast for a half-minute or so. In doing this the beginner is likely to find difficulty in breathing and blowing at one and the same time. When blowing he is apt to "hold his breath." This can be overcome with a little practice. Before placing the end of the mouth-piece between the lips, expand the cheeks, keeping the mouth closed, and breathe through the nostrils for intervals of a half-minute or more. Afterwards do the same with the blowpipe in position. It will then be found that a blast can be kept up on a flame with little difficulty. Do not try to get too strong a blast at first. Simply keep up a good pressure on the cheeks.

Fuel and Flames.—The best source of heat for blowpipe work is the Bunsen gas burner. The orifice, at the bottom of the burner, for admitting air is kept closed when the blowpipe is in use, and left open when it is desired to use simply the heat of the flame. Where gas is not available, paraffin, wax or other candles can be employed. As they melt rather rapidly when used with the blowpipe, it is best to use them in another way. Whittle the paraffin from the candle, keeping the wick whole, or get a piece of paraffin such as is commonly on sale in drug stores, and make use of a tin box, preferably rectangular in form, as a receptacle for the paraffin. This box need not be more than one and one-half inches in width with a height of one inch. A wick is placed in a piece of iron or brass tubing with diameter of one-quarter inch, and length, for the size of box mentioned, of one and one-quarter inch. Brass tubing is better than iron, since after it becomes heated by the flame, it tends to keep the paraffin more perfectly melted. The wick holder may be soldered in one corner of the box, or it may be stood upright with the wick in it and the box filled nearly full of paraffin, tallow or other substance used as fuel. Sufficient wick should be used to form a support for the holder on the bottom of the box. The holder should project above the edge of the box. It will be found that water can be caused to boil in a glass tube if the latter is held at the uppermost edge of the paraffin flame. In this position the tube will not become coated with soot.

In blowpiping we make use of two flames, known as the oxidizing flame, O.F., and the reducing flame, R.F. The diagrams (Figs. 105, 106), will make clear the methods of producing these. It will be seen that in using the O.F. the tip of the blowpipe is inserted halfway into the flame. Oxygen is thus added to the centre of the flame, bringing about more perfect combustion and destroying the reducing action possessed by the gases and the minute particles of carbon. The diagram (Fig. 105) shows that the test substance, when using the O.F., comes under conditions favorable for oxidation. From diagram (Fig. 106) it is seen that the test substance, when the R.F. is used, is subjected to the action of the interior of the flame, which has an avidity for oxygen. It thus tends to take this element from the substance under

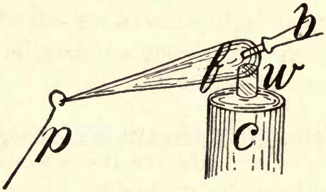


FIG. 105.

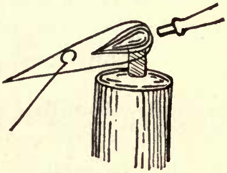


FIG. 106.

FIG. 105. Method of producing the oxidizing flame (O.F.). *c*, candle or lamp; *w*, wick; *b*, tip of blowpipe; *f*, flame; *p*, platinum wire with loop on it, showing the position in which the test substance is held when being submitted to the oxidizing flame.

FIG. 106. The loop of the platinum wire shows the position in which the test substance is held when using the reducing flame (R.F.).

examination, or, in other words, to reduce it to a lower state of oxidation.

Alcohol lamps are at times used in blowpiping, but their flames, unless turpentine or some similar material is added, are not so suitable for producing a reducing flame.

Forceps.—These are used for holding small splinters or fragments of minerals when testing their fusibility or flame coloration. Platinum-tipped forceps are the best, but the common steel variety, about four inches in length, serve most purposes (Fig. 107).

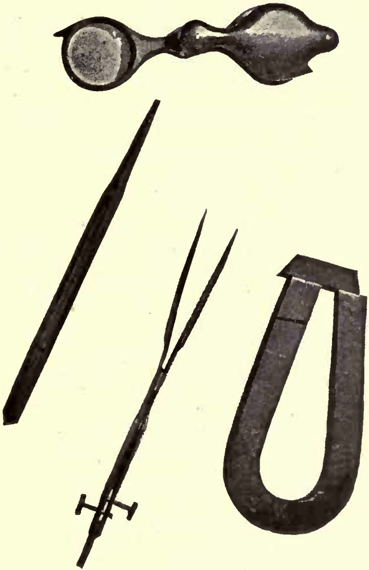


FIG. 107.—Magnifying glass; small three-cornered file; forceps; horse-shoe magnet.

Platinum Wire.—A piece of wire, of the size known as No. 27, about three inches in length, is required. For convenience in handling, one end of the wire may be fused into a short piece of small sized glass tubing. Before using, a small loop about one-tenth inch in diameter is formed on the end of the wire.

Glass Tubes.—The open tubes consist of a piece of tubing three or four inches in length and one-eighth to one-quarter inch in diameter. By cutting a nick in a piece of tubing with a small three-cornered file, the requisite lengths can be broken off. If a piece of tubing seven or eight inches in length be heated in the middle until the glass is soft enough to be drawn apart, we can make two pieces of tubing each with one end closed, which are known as closed tubes (Fig. 110). The glass should be of the hard variety.

Charcoal.—Soft wood makes the best charcoal for blowpipe work. It should be thoroughly burned, otherwise it will tend to crack and fly to pieces when heated. The pieces of charcoal should be rectangular in form, four inches or more in length and about two inches in breadth. The diagram (Fig. 108) shows such a piece on which a little zinc had been oxidized with the blowpipe.

File and Magnet.—These have been referred to in describing the physical characters of minerals.

Magnifying Glass.—A common pocket lens is frequently very useful in examining minerals or blowpipe products.

Chemical Reagents.—The chief reagents used in blowpiping embrace borax (sodium biborate) or borax glass, phosphor salt (phosphate of sodium and ammonia), soda (carbonate of soda), and cobalt solution (nitrate of cobalt).

Frequent use is made of the common acids—hydrochloric (muriatic), sulphuric and nitric. A few test tubes are needed. If they are not at hand, a small bottle or vial will sometimes serve the purpose.

In testing for carbonates, the organic acid—citric—may be employed. It can be obtained in the solid form and is thus more convenient to carry than the mineral acids just mentioned. When powdered it dissolves readily in water and is then ready for use. Acetic acid, another organic acid, is well known in the form of vinegar.

Complete sets of blowpipe apparatus and reagents can be purchased at moderate cost. They may be ordered through most druggists.

EXPERIMENTS.

Dissolving in Acids.—If a drop or two of acid is placed on the surface of certain mineral specimens, or on their powder, gas is given off, shown by the formation of bubbles, or what is known as effervescence takes place; prospectors sometimes wrongly say the specimen "burns." In all cases it is best to powder the substance and drop a few minute grains into cold acid in a test tube. The effervescence of calcium carbonate or calcite under these conditions is very distinct. The closely related calcium-magnesium carbonate, dolomite, which occurs as a common mineral, and certain other carbonates effervesce only in heated acid. Test a few samples of common clay for carbonates, which are frequently present as impurities. Mineral specimens are at times more or less porous. If acid is dropped on the surface of such a specimen it will work down through cracks, drive out the air, and in some cases the air bubbles may be mistaken for those produced by effervescence.

Various silicates when finely pulverized gelatinize in acids. Boiling hydrochloric acid is generally required to bring about the effect. The gelatinous material consists of silica.

Sulphuretted hydrogen, known by its odor, is evolved from some sulphides, *e.g.*, sphalerite and pyrrhotite, if the powdered mineral is boiled with hydrochloric acid.

Copper and certain of its compounds dissolve in nitric acid, the resultant solution possessing a characteristic green or bluish-green color. Immerse a piece of iron or steel in a diluted solution of this kind. Note the character of the deposit formed on the surface of the immersed material.

The production of chlorine by the action of hydrochloric acid on manganese dioxide is a well known experiment in the chemical laboratory.

Quartz, acid feldspars, and many other minerals are not acted on by common acids.

Fusibility.—In testing the fusibility of a mineral in the forceps a small splinter or fragment should be held so that a fine point or edge can be exposed to the tip of the oxidizing flame without heating the forceps. If a mineral tends to fly to pieces when thus heated, or if it fuses easily or is of such a nature that it will attack the tip of the forceps when heated, charcoal should be used as a support.

If the fine point or edge of the fragment fuses to a glass when it is exposed to the flame, the mineral is readily fusible; if the edge is only slightly rounded, it is fusible with difficulty. Test fragments of feldspar, gypsum, barite, and garnet.

Flame Coloration.—Certain minerals when thus heated in the forceps impart a characteristic color to the flame. Heat a small piece of thin copper wire or a small shaving of copper or brass in the flame. Then moisten the wire with a drop of hydrochloric acid and heat again. Note the color of the flame in each case. Place a few grains of common salt in a small cavity in a piece of charcoal and heat gently. The coloration of the flame is due to sodium. If the salt tends to fly off the charcoal, moisten it slightly and heat again. Test for flame-coloration of potash in saltpetre in the same way. Moisten the loop of a platinum wire, described under a later heading, dip it in salt or nitre and note the color imparted to the flame. Mix a little salt with an equal portion of nitre. It will be found that the sodium color alone is shown in heating the mixture on the platinum wire. Note the appearance of the flame when viewed through deeply colored blue glass.

Use of Cobalt Solution.—Certain infusible, slightly colored aluminous minerals, moistened with nitrate of cobalt and then strongly heated take on a characteristic blue color. Zinc oxide in the form of a deposit on charcoal, for example, becomes green; and slightly-colored magnesia compounds become red, when similarly treated.

Experiments on Charcoal.—A small quantity of the mineral or other substance to be tested is placed in a shallow cavity, formed by the point of a pocket knife, in one end of a piece of charcoal (Fig. 108). The charcoal is held in the left hand so that the blowpipe flame can be directed upon the substance in the cavity. The test-matter may tend to decrepitate or fly away when the flame is applied to it. If this happens it should be reduced to powder and made into a paste with water. It will then adhere to the charcoal when heated gradually. A mineral fragment may also be kept from flying from its support by putting a minute quantity of borax in the charcoal cavity in which it is being heated.

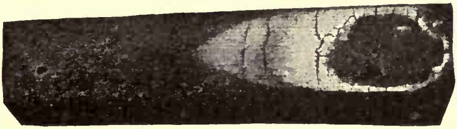


FIG. 108.
Charcoal on which a little zinc has been oxidized by the blowpipe.
(About one-half natural size.)

EXPERIMENTS.—(1) Heat a small shaving of lead first with the reducing flame, and after having fused it to a bead, apply the oxidizing flame. What is the color of the coating or sublimate deposited on the charcoal? Determine the color of the deposit produced by treating zinc in the same way. Is this zinc deposit the same color when cold as when hot? A piece of the alloy, known as soldering metal, can be obtained in most localities. Heat a fragment of it and note the results.

(2) In the reducing flame on charcoal, especially if sodium carbonate is used as a flux, several metals, in natural and artificial compounds, can be reduced to the metallic state. If the amount of fusible metal in the test matter is small, or if the metal is reducible with difficulty, we proceed as follows: A small portion of the test-matter in powder—previously roasted if it is an arsenide or sulphide—is mixed with three or four times its quantity, by volume, of sodium carbonate into a coherent mass with a little water. The mass is then subjected to the reducing flame on charcoal. If a readily fusible metal is present little metallic globules will gradually form. With a little care these can be caused to run into one. Test galena in this way. Try a little iron rust or ferric oxide in the same manner. After having subjected the iron oxide to the action of sodium carbonate and the reducing flame for about half a minute, separate the fused mass from the charcoal, with the point of a knife, crush it to powder in a small mortar (Fig. 109) or on an anvil and see if any portion of it is magnetic.

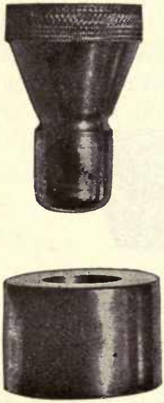


FIG. 109.
Steel mortar and pestle used in crushing minerals for blow-pipe work.

(3) Heat a little sulphur in the cavity in charcoal. Try a fragment of coal, preferably the soft variety, in the same way. A few minerals burn when so treated. Note the odor given off by the sulphur and by the coal. Heat a grain of pyrite, and one of mispickel, and note the odor in each case.

(4) The fusibility of minerals may be determined on charcoal if a pair of forceps is not at hand.

Roasting on Charcoal.—This operation is employed to eliminate the sulphur in sulphides, the arsenic in arsenides, and other volatile matter from the mineral under examination, before proceeding with certain tests. Both sulphur and arsenic, for example, when in the volatile form, attack platinum, and must be removed before the substance containing them is tested in borax, or phosphor salt beads on the wire of this metal.

A small piece of the mineral to be roasted is reduced to fine powder, moistened, and spread on the surface of charcoal. It is then ignited before the point of the oxidizing flame, and heated gently at first, to prevent fusion. If it fuses it should be again reduced to powder. When the material is completely roasted, it will cease to give off an odor. The color or other character of the thoroughly roasted material is often characteristic. Iron pyrites, for instance, leaves a magnetic residue. Some minerals (*e.g.*, stibnite and sphalerite) form a coating, surrounding the test substance, on the charcoal.

Detection of Sulphur in Sulphides and Sulphates.—With the exception of certain specimens of zinc blende, nearly all naturally occurring sulphides possess a metallic lustre. The streak of all of them, zinc blende included, is distinctly colored. The natural sulphates do not possess a metallic aspect, and their streak is either colorless or pale green or blue. With few exceptions the sulphides emit an odor of sulphur when heated, while the sulphates do not.

EXPERIMENT.—Fuse a little of the substance, a sulphide or a sulphate, in powder, with two or three times its volume of carbonate of soda, and a little borax, in a good reducing flame on charcoal. A reddish or dark mass is formed, which, if moistened and placed on a silver coin, produces a dark stain. Test pyrite, galena, sphalerite, gypsum, and barite.

Fusion with Borax and Salt of Phosphorus.—Certain elements give characteristic colors to glasses formed of these reagents when the substance under examination is fused into them. The glasses are formed as follows: The loop on the end of a piece of platinum wire is heated, or slightly moistened, and dipped into the reagent, a small quantity of which will cling to it. The loop is then heated in the oxidizing flame till the borax or phosphor salt is melted to a glass (Fig. 105). The loop is again dipped into the reagent and a further quantity is taken up and fused. This is continued till a glass bead has been formed which fills up the loop. The substance to be tested should be reduced to a fine powder, and roasted if sulphur or arsenic be present. The glass bead in the loop is heated or moistened and dipped into the substance under examination so that a very small amount of the powder adheres to it. The bead is then fused, gently at first, so that the powder will melt gradually into the glass. It will be found that the colors thus imparted to the glass serve as very delicate tests for the presence of certain metals. The colored beads, after cooling, can be readily freed from the loop by gently uncoiling the wire. Some glass beads thus formed will be found to be good imitations of certain gem stones.

BORAX BEADS.

The following table shows the characteristic colors imparted to beads of borax when certain metals or their compounds are fused into the beads in either the oxidizing or reducing flames. The phosphor salt glasses are for the greater part similar to those of borax, but are usually somewhat less deeply colored.

The portion of test-matter added to the bead must be very small, otherwise the glass may become so deeply colored as to appear quite black. In this case the color may be observed by flattening the bead on a small anvil or pinching it between the forceps before it has time to cool. If two or more metals occur together the colors imparted to the beads may be indistinct.

COLOR OF BEAD AFTER EXPOSURE TO AN OXIDIZING FLAME.	BORAX.	COLOR OF BEAD AFTER EXPOSURE TO A REDUCING FLAME.
	COMPOUNDS OF—	
Green (whilst hot) Blue or greenish-blue (cold)	Copper	More or less colorless or indistinctly colored whilst hot; brownish-red and opaque on cooling.
Blue (very intense)	Cobalt	Blue (very deep).
Yellowish or reddish (hot)	Chromium	Emerald green.
Yellowish or reddish	Iron	Bottle-green.
Violet or amethystine	Manganese	Colorless, if quickly cooled. Violet red, if slowly cooled.
Violet-brown (whilst hot) Clear brown (when cold)	Nickel	Grey, opaque and magnetic.

SODIUM CARBONATE.

The green color imparted to a bead of sodium carbonate by manganese is a very delicate test for this metal. A small portion of sodium carbonate is moistened and kneaded in the palm of the left hand by a knife point or a small spatula. The slightly cohering paste thus formed is placed on the loop of platinum wire and fused into a bead. The test-matter is then added to it as in the case of the borax bead.

EXPERIMENTS.

For practice in forming colored beads, a number of common substances are available. Determine what colors are given to the borax bead by each of the following: iron rust; a small grain of cobalt nitrate, or by dipping the bead on a wire into the pink solution of this salt; a small fragment of a deep blue glass; a piece of a small black so-called jet bead such as is commonly used for ornamental purposes; a small shaving of copper or brass; a little potassium bichromate. Numerous salts of the metals given in the table are obtainable if access can be had to a chemical laboratory. Compounds of most of them can be purchased in any drug store. Test for the presence of iron in magnetite, and iron pyrites (after roasting), and for copper in malachite and copper pyrites (after roasting).

Detection of Silica.

Beads of phosphor salt are useful for the detection of silica in silicates. The silica remains for the most part undissolved in a bead, in the form of a translucent, flocculent mass known as a silica skeleton, the associated constituents being gradually taken up by the flux. Test a minute fragment of feldspar or mica.

Form a strongly colored phosphor salt glass by adding copper, preferably in the form of black oxide, to a bead on platinum wire. Then attach a little common salt to the bead and expose to the point of the blue cone of the blowpipe flame. Note the color imparted to the flame. This is a test for chlorides.

Water Test.—The presence of water in gypsum, and other hydrous minerals, can be detected by heating a small fragment of the mineral in a closed or open tube, either by the flame of a lamp or by the blowpipe, as shown in Figs. 110, 111. The water, on being expelled, gathers in the form of moisture in the tube. The tube should be thoroughly dried before the experiment is begun.

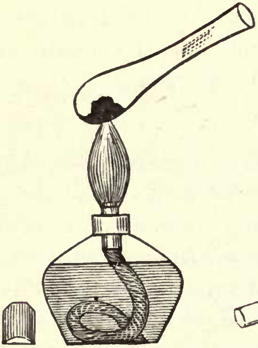


Fig. 110.

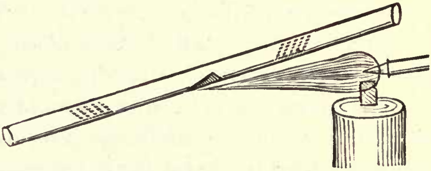


Fig. 111.

Fig. 110. The Water Test in the Closed Tube. The illustration shows the substance being heated in the tube by a spirit-lamp.

Fig. 111. The Water Test in the Open Tube. The substance is being heated with the point of the blowpipe flame.

As a review exercise, the reader should draw up a list of the chief chemical and blowpipe tests for the minerals on pages 50 to 53. Consult Part II, pages 54 to 112, and Appendix I. In cases where notes on the fusibility and other characteristics of certain minerals are not given the reader should determine the characteristics for himself. In preparing the list, the following points may be considered:—

(1) Tests with acids.

(2) Fusibility.

(3) Flame coloration.

(4) Before the blowpipe on charcoal:—*a*, odor; *b*, fusibility; *c*, deposit on the charcoal; *d*, reduction with sodium carbonate, and the test for sulphur in sulphides and sulphates.

(5) Fusion with borax or phosphor-salt on platinum wire.

(6) Silica test with phosphor-salt.

(7) Test for chloride.

(8) Water test.

APPENDIX II

TABLE OF THE ELEMENTS.

For convenience, the *elements*, or those substances which cannot, by means now employed, be divided into constituents and cannot be formed by the union of others, are represented by the first letter of their names, derived either from the Latin or Greek. Where two or more elements happen to have the same initial letter, a second small letter is added to the capital. Hydrogen is represented by H, from hydrogenium; mercury by Hg, from hydrargyrum; fluorine by F, and iron by Fe, from ferrum. These letters are known as the *symbols* of the elements. The symbols also represent the combining proportions, by weight, of the elements. These proportions are known as the *atomic weights* of the elements—that of hydrogen being taken as unity.

The following table gives the symbols and atomic weights of some of the more important elements, the total number being about 70. The weights are given for the most part in round numbers, the decimals being neglected. In comparing the tables in various books, the reader will observe that the authors do not give exactly the same atomic weights. Hence, for the purpose of this book, it was thought best to take chiefly round numbers, which represent approximately the averages given by other authors.

Compounds formed by the union of the elements are represented by placing the symbols of the elements together. Thus the compound known as galena or lead sulphide is represented by the *chemical formula* PbS, and barium sulphate or barite—a compound of barium, sulphur, and oxygen—is represented by the formula $BaSO_4$. These chemical formulas also represent the relative proportions by weight according to

ELEMENT.	SYMBOL.	ATOMIC WEIGHT	ELEMENT.	SYMBOL.	ATOMIC WEIGHT
Aluminium	Al	27	Mercury	Hg	200
Antimony (Stibium)	Sb	120	Molybdenum	Mo	95.5
Arsenic	As	75	Nickel	Ni	59
Barium	Ba	137	Nitrogen	N	14
Bismuth	Bi	208.5	Oxygen	O	16
Bromine	Br	80	Phosphorus	P	31
Cadmium	Cd	112	Platinum	Pt	197
Calcium	Ca	40	Potassium (Kalium)	K	39
Carbon	C	12	Silver (Argentum)	Ag	107.5
Chlorine	Cl	35.5	Silicon	Si	28
Chromium	Cr	52	Sodium (Natrium)	Na	23
Cobalt	Co	59	Strontium	Sr	87.5
Copper (Cuprum)	Cu	63.6	Sulphur	S	32
Fluorine	F	19	Tin (Stannum)	Sn	119
Gold (Aurum)	Au	197	Titanium	Ti	48
Hydrogen	H	1	Tungsten (Wolfram)	W	184
Iron	Fe	56	Uranium	Ur	240
Lead (Plumbum)	Pb	206.9	Vanadium	Vd	51
Magnesium	Mg	24	Zinc	Zn	65.4
Manganese	Mn	55	Zirconium	Zr	90.5

which the elements unite. Thus Pb represents 206.9 parts by weight of lead, and S, 32 parts by weight of sulphur.

The chemical union of atoms produces the smallest particles of compound bodies, known as *molecules.* The molecule of barium sulphate contains, therefore, by weight 137 parts of barium, 32 of sulphur, and 4 × 16 or 64 parts of oxygen—or it contains 1 atom of copper, 1 of sulphur and 4 of oxygen.

The percentage composition of galena, PbS, can be calculated as follows:—

		In per cent.
Lead, Pb	= 206.9	86.6
Sulphur, S	= 32	13.4
	238.9	100.00

$$\text{that is } \left(\frac{206.9}{238.9} \text{ of } 100 = 86.6, \text{ and } \frac{32}{238.9} \text{ of } 100 = 13.4\right).$$

Calculate the percentage composition of pyrite FeS_2, ma netite Fe_3O_4, and orthoclase $KAlSi_3O_8$.

A substance is found to have the following percenta composition:—Bismuth 81.2, sulphur 18.8. Determine it chemical formula.

$CaCO_3 + 2HCl = CaCl_2 + CO_2 + H_2O$. This represents wha is known as a *chemical equation.* It represents the action of hydrochloric acid on calcium carbonate or limestone, calcium chloride, carbon dioxide and water resulting. The equation shows that one molecule of calcium carbonate is acted on by two of hydrochloric acid.

The reader who has little or no chemical knowledge should procure some elementary work on chemistry. A knowledge of chemistry is essential to the mineralogist.

APPENDIX III

ILLUSTRATIONS OF PRE-CARBONIFEROUS FOSSILS

(after Chapman).

The following illustrations represent some of the more characteristic Paleozoic fossils. The relationships of the formations, mentioned in connection with each illustration, are shown on the map, page 161.

1.—FOSSIL PLANTS.

(a) Algæ or "fucoids" (Figs. 112–118).

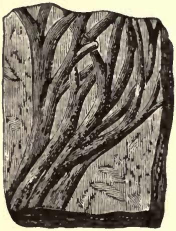


Fig. 112
Lithrophycus Ottawaensis.
Trenton Formation.

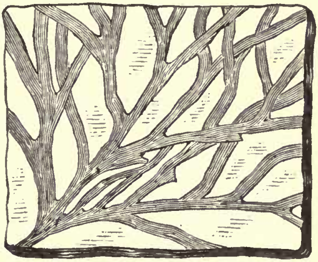


Fig. 113
Bythotrephis tenuis.
Medina and Clinton Formations.

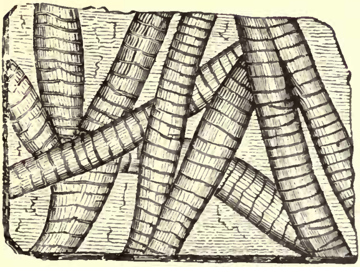


Fig. 114
Arthrophycus Harlani.
Medina and Clinton Formations.

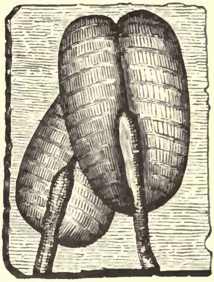


Fig. 115
Rusophycus bilobatus.
Medina and Clinton.

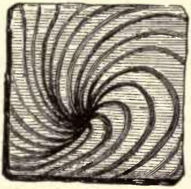


Fig. 116
Fucoides (=Spirophyton) cauda-galli.
Portage-Chemung Formation.

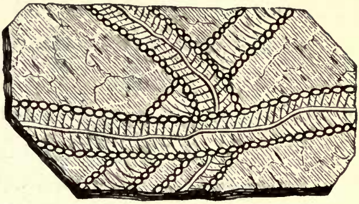


Fig. 117
Climactichnites Wilsoni.
Potsdam Formation.

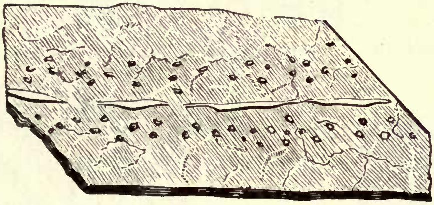


Fig. 118
Protichnites.
Potsdam Formation.

The impressions known as *Climactichnites* and *Protichnites*, which occur in the Potsdam formation in the vicinity of the town of Perth, Ontario, have been commonly regarded as the tracks of crustacea, but they should probably be referred to algæ.

(b) Equisetaceæ.

This group is represented by one living genus, *Equisetum*, common species of which are known as "horsetails," scouring rushes, etc. Fossil forms are chiefly represented by *Calamites*, which are abundant in Devonian and Carboniferous beds.

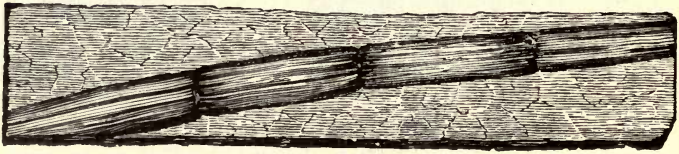


Fig. 119
Calamites inornatus.
Portage-Chemung Formation.

(c) LEPIDODENDRACEÆ.

This group, represented typically by the fossil genera, *Lepidodendron* and *Sigillaria*, are entirely Paleozoic. Very probably these extinct types represent connecting links between the higher cryptograms and the gymnosperms of existing nature. Their remains are found in the Devonian, and in great abundance in the coal beds of the Carboniferous, where they are represented in most cases by casts of tree stems, usually fragmentary, but occasionally in lengths of more than 30 or 40 feet.

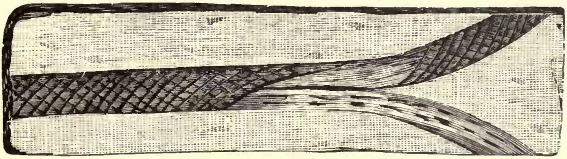


FIG. 120
Lepidodendron Gaspianum.
Devonian, Gaspé.

Impressions of long, narrow, parallel-veined leaves, supposed to be the leaves of lepidodendroids, are referred to *Cordaites* (Fig. 121).

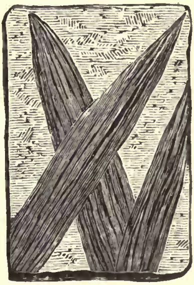


FIG. 121
Cordaites angustifolia.
Devonian, Gaspé.

2.—ANIMAL REMAINS.

A.—INVERTEBRATES.

(a) GRAPTOLITES.

Fossils of the extinct, lowly organized group of animals known as graptolites (from *graptos*, engraved or written, and *lithos*, stone) occur typically as delicate impressions or markings on shale or slate. The annexed figures (122 to 128) show some of the more common or characteristic forms.

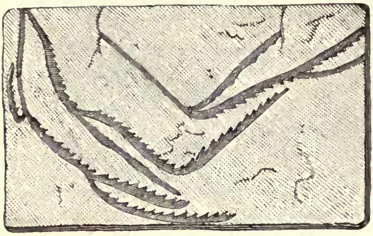


Fig. 122
Graptolithus (Didymograptus) flexilis.
Levis Formation.

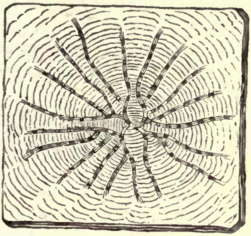


Fig. 123
G. (Loganograptus) Logani.

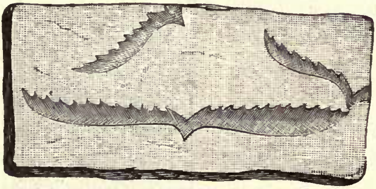


Fig. 124
G. (Didymograptus) pennatulus.

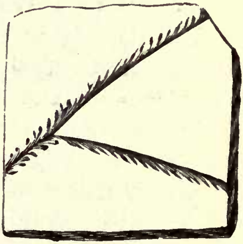


Fig. 125
G. (Dicranograptus) ramosus

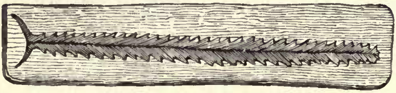


Fig. 126
G. (Climacograptus) bicornis.
Utica and Hudson River Formations.

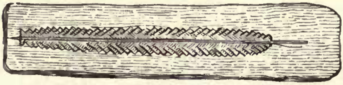


Fig. 127
G. (Diplograptus) pristis.
Utica and Hudson River Formations.

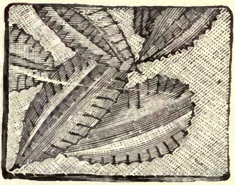


Fig. 128
G. (Phyllograptus) typus.
Calciferous Formation.

(*b*) CORALS.

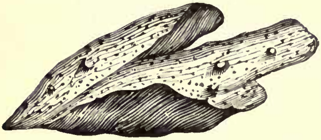


FIG. 129.—*Monticulipora (Stenopora or Chœtetes) fibrosa.*
Trenton and Hudson River Formations.

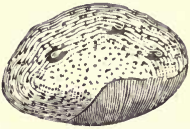


FIG. 130.—*M. petropolitana.*
Trenton and Hudson River Formations

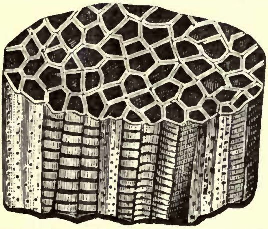


FIG. 131.—*Favosites Gothlandica.*
Silurian and Devonian.

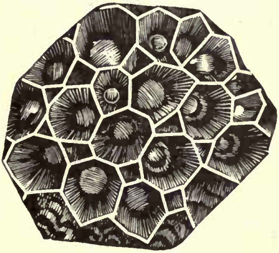


FIG. 132.—*Michelinea convexa.*
Devonian.

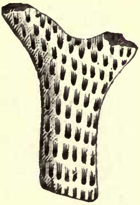


FIG. 133.—*Alveolites cryptodens*
Devonian.

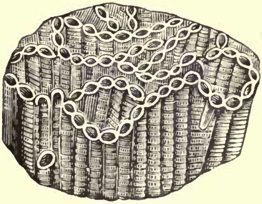


FIG. 134.—*Halysites catenulatus.*
Niagara Formation.

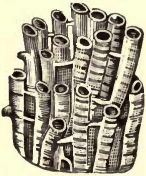


FIG. 135.—*Syringopora Maclurea.*
Devonian.

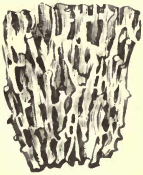


FIG. 136.—*S. Hisingeri.*
Devonian.

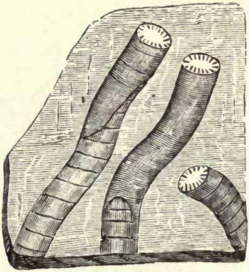


FIG. 137.—*Amplexus laxatus.*
Devonian.

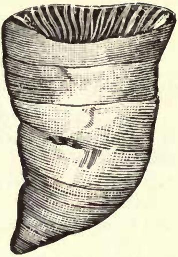


FIG. 138.—*Zaphrentis prolifica.*
Devonian.

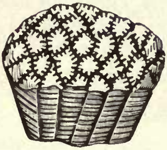


FIG. 139.-*Columnaria alveolata*(*Goldfuss.*)
Black River (Trenton) Formation.

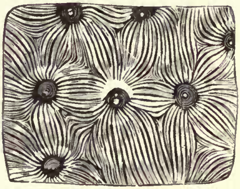


FIG. 140.—*Phillipsastrœa.*
Devonian.

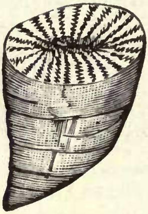


FIG. 141.—*Heliophyllum Halli.*
Devonian.

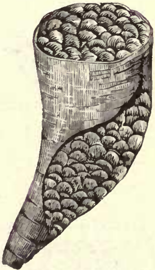


FIG. 142.—*Cystiphyllum Senecaense*
Devonian.

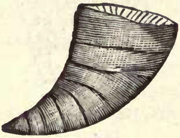


FIG. 143.—*Petraia.*
Lower Silurian.

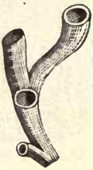
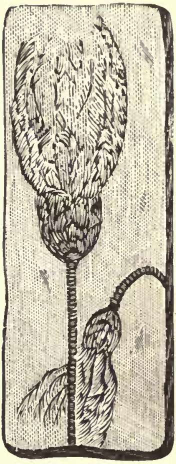


FIG. 144.—*Aulopora cornuta.*
Devonian.

(c) CRINOIDS.



This class comprises the various so-called "sea-lilies" now almost extinct. The crinoids are attached typically to the sea-floor by a comparatively long, flexible stem (Fig. 146). The flower-like top is much rarer in the fossil state than are fragments of the stem, which occur in great abundance in some rocks.

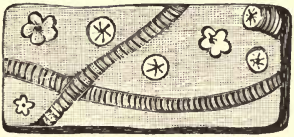


FIG. 145.
Crinoid stem-fragments.

FIG. 146.
Crinoid, "stone-lily."

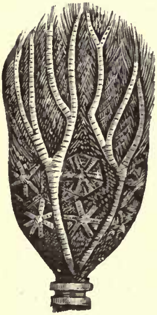


FIG. 147.
Glyptocrinus decadactylus.
Silurian.

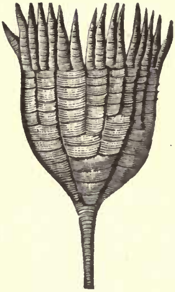


FIG. 148.
Ichthyocrinus lævis.
Niagara Formation.

(*d*) STAR FISH AND RELATED FORMS.

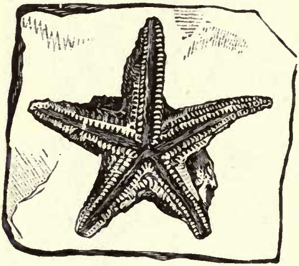


FIG. 149.
Petraster Bellulus.
Niagara Formation.

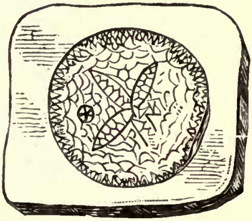


FIG. 150.
Hemicystites (*Agelacrinites*) *Billingsii.*
Trenton Formation.

(*e*) TRILOBITES.

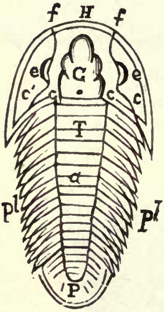


FIG. 151.

This is a very interesting, extinct group of animals. They belong to the class known as the crustacea, which includes the crabs, lobsters and other forms of existing nature.

As shown in fig. 151, the upper covering or "back" of the trilobite consists of three principal parts, (1) the *buckler* or *head-shield*, H; (2) the *body* or *thorax*, T; and (3) the *pygidium* or *caudal*-shield, P.

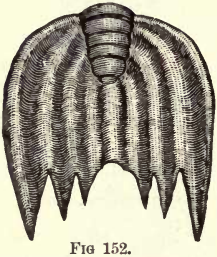


FIG 152.
Dikelocephalus magnificus
(pygidium only)
Levis Formation.

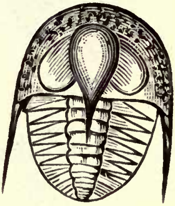


FIG. 153.
Trinucleus concentricus.
Trenton and Hudson River Formations.

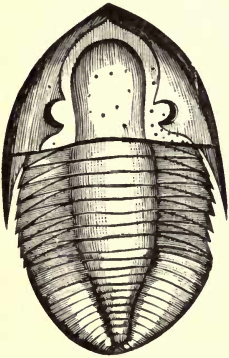


FIG. 154.
Asaphus Canadensis.
Utica Formation.

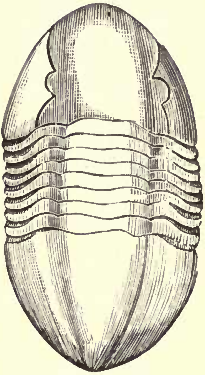


FIG. 155.
Asaphus platycephalus.
Trenton Formation.

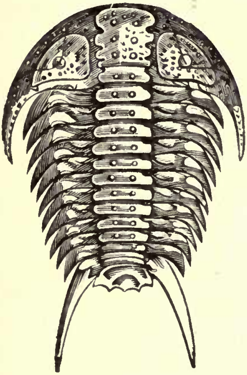


FIG. 156.
Ceraurus (=Cheirurus) plenrexanthemus.
Trenton Formation.

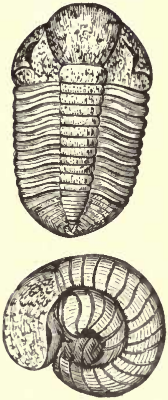


FIG. 157.
Phacops Bufo.
Corniferous and Hamilton Formations.

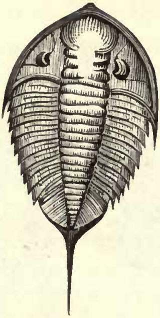


Fig. 158.—*Dalmanites limalurus.* Niagara Formation.

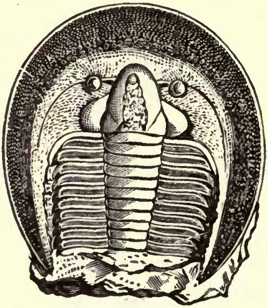


Fig. 159.—*Harpes Ottawaensis.* Trenton Formation.

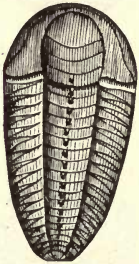


Fig. 160.—*Triarthrus Beckii.* Utica Formation.

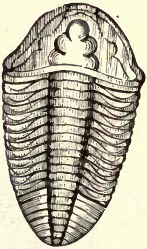


Fig. 161.—*Calymene Blumenbachii.* Trenton, Hudson River and Niagara Formations.

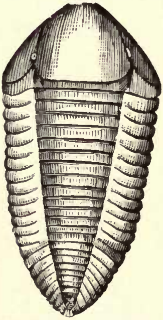


Fig. 162.—*Homalonotus delphinocephalus.* Niagara Formation.

(*f*) MOLLUSCA.

The reader will see that many of the members of this group resemble living forms.

1.—Brachiopods.

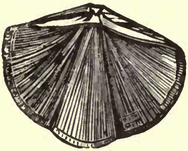


FIG. 163.
Spirifer radiatus.
Niagara Formation.

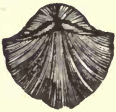


FIG. 164.
Spirifer gregarius.
Corniferous Formation.

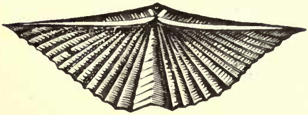


FIG. 165.
Spirifer mucronatus.
Devonian.

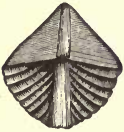


FIG. 166.
Cyrtina.
Devonian.

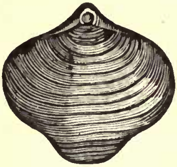


FIG. 167.
Spirigera (Athyris) concentrica.
Devonian.

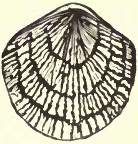


FIG. 168.
Atrypa reticularis.
Upper Silurian, Devonian.

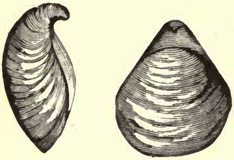


FIG. 169.
Centronella-glans fagea.
Devonian.

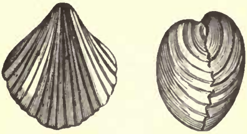


FIG. 170.
Rhynconella plena.
Chazy Formation.

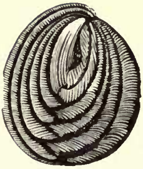


Fig. 171.—*Rhynconella increbescens.*
Trenton Formation.

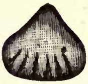


Fig. 172.—*Rhynconella (Camerella) varians.*
Chazy Formation.

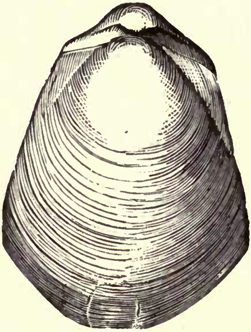


Fig. 173.—*Pentamerus oblongus.*
Clinton and Niagara Formations.

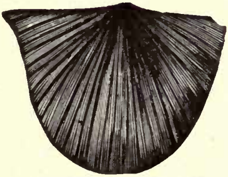


Fig. 174.—*Strophomena alternata.*
Trenton and Hudson River Formations.

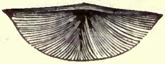


Fig. 175.—*Leptæna sericea.*
Trenton and Hudson River Formations.

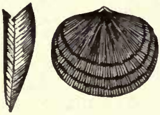


Fig. 176.—*Orthis tesutdinaria.*
Trenton and Hudson River
Formations.

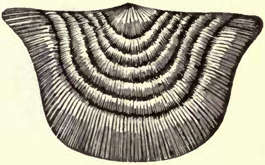


Fig. 177.—*Strophomena rhomboidalis.*
Upper Silurian and Devonian.

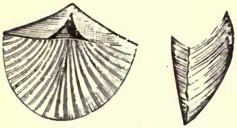


FIG. 178.
Orthis tricenaria.
Trenton Formation.

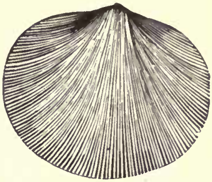


FIG. 179.
Orthis vanuxemi.
Devonian.

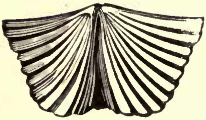


FIG. 180.
Platystrophia lynx.
Trenton Formation.

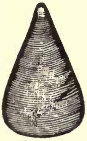


FIG. 181.
Lingula acuminata
(=*L. antiqua*).
Potsdam Formation.

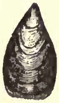


FIG. 182.
Lingula oblonga.
Medina and Clinton
Formations.

2—Mollusca Vera.

(A)—LAMELLIBRANCHS.

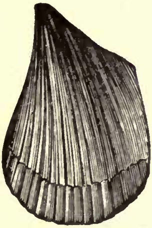


FIG. 183.
Ambonychia radiata.
Trenton and Hudson River
Formations.

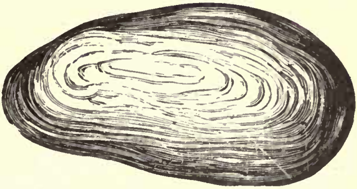


FIG. 184.
Modiolopsis modiolaris.
Hudson River Formation.

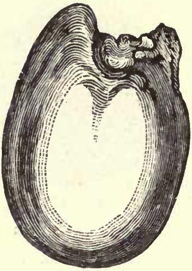


FIG. 185.

Cast of *Megalomus (Cyrtodonta) Canadensis.*

Guelph Formation.

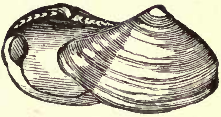


FIG. 186.

Leda truncata.

Post Glacial.

(B)—GASTEROPODS.

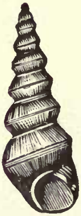


FIG. 187.

Murchisonia gracilis.

Trenton and Hudson River Formations.

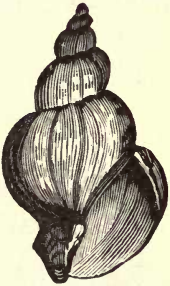


FIG. 188.

Buccinum undatum.

Post-Cenozoic and living.

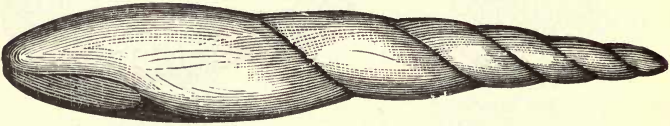


FIG. 189.

Subulites elongatus. (Internal cast).

Lower Silurian.

(C)—CEPHALOPODS.

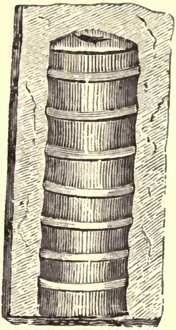


Fig. 190.
Orthoceras Lamarcki.
Calciferous Formation.

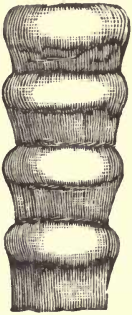


Fig. 191.
Part of siphuncle, natural size, of
Orthoceras (Huronia) vertebrale.
Niagara Formation, Lake Huron.

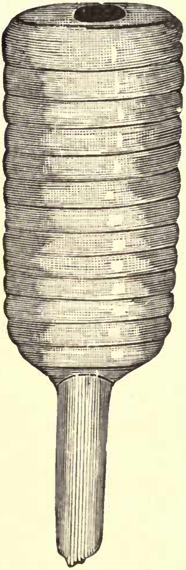


Fig. 192.
Orthoceras (Endoceras) proteiforme.
Trenton Formation.

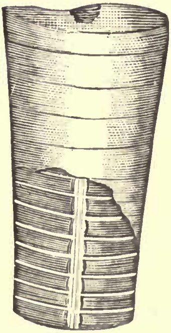


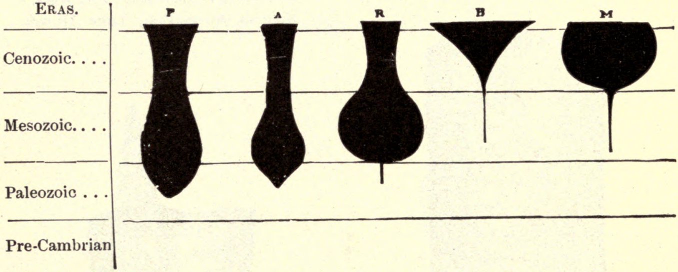
Fig. 193.
Orthoceras (Ormoceras) crebriseptum.
Hudson River Formation.

A figure of an ammonite, another representative of the cephalopods, is given on page 19.

B.—VERTEBRATES.

It has been shown, on preceding pages, that the vertebrates were of less importance in the Paleozoic than in succeeding times.

The annexed diagram shows, in a general way, the life-range and relative importance, during the various eras of the earth's history, of the various classes of Vertebrates, viz., (F) Fishes, (A) Amphibians, (R) Reptiles, (B) Birds, (M) Mammals.



APPENDIX IV

PRICES OF MINERALS, ORES, AND METALS.

The prices of most of these substances are constantly changing. Those given in the following table are the market quotations for the early part of 1906. It is impossible to state a price for many ores, owing to the fact that the cost of extracting the metals from them is so variable.

SUBSTANCE.	UNIT.	PRICE	REMARKS.
ABRASIVES—			
Corundum . . .	Lb.	$ .05- .10	In the form of grains.
Emery	"	.05	Best ground.
Garnet	Ton.	25.00- 35.00	
Grindstones .	"	10.00	
Diatomaceous Earth	"	20.00- 40.00	Best ground.
Arsenic, White Oxide	"	60.00-100.00	
Asbestos	"	175.00-200.00	Best grade, crude.
Barite	"	7.00	
Bauxite	"	5.00	
Cement, Portl'd		2.00	Barrel, 400 lbs.
Chalk	"	3.00	Bulk.
Chrome Ore . . .	"	25.00	
Clay, Fire	"	5.00	Ordinary.
Coal	. . . .	. . . .	See local market quotations.
Cobalt Oxide . .	Lb.	2.50	
Cryolite	"	.06½	
Feldspar	Ton.	9.00	Ground.
Fluorspar	"	10.00- 15.00	
Graphite	"	150.00	Best flake.

PRICES OF MINERALS, ORES, AND METALS—*Continued.*

SUBSTANCE.	UNIT.	PRICE.	REMARKS.
Gypsum	Ton.	$ 8.00	Ground.
Iron Ore	"	4.00	Price only approximate, depends on quality.
Kaolin	"	8.00– 15.00	
Lime	250 lb. Barrel.	.80	
Magnesite	Ton.	5.00	Crude.
Mica	Lb.	....	Depends on size of sheets, *e.g.*, 1 in. x 3 in. = 12c. ; 3 in. x 5 in. = 55c.
Pyrite	Ton.	5.00– 6.00	Containing about 45 % Sulphur.
Petroleum	Barrel.	1.50	Crude, Canada.
Slate, Roofing	Square.	2.25– 10.50	"Square" = 100 sq. ft., or laid on roof.
Soapstone	Ton.	11.00	
Sulphur	100 Lbs.	2.00	
Talc	Ton.	20.00	First Grade.
METALS—			
Aluminium	Lb.	.35	
Antimony	"	.07	
Bismuth	"	2.10	
Copper	"	.18	High price.
Cobalt	"	2.50	See Cobalt Oxide.
Gold	Troy Oz.	20.67	
Iron	Ton.	15.00	Pig Iron.
Lead	Lb.	.05½	
Mercury	"	.53	
Molybdenum	"	1.75	
Nickel	"	.40– .60	
Platinum	Troy Oz.	20.50	
Silver	"	.64	
Tin	Lb.	.36	
Zinc	"	.06½	

APPENDIX V

The following list contains the names of a few books which can be procured through any bookseller. Some of the more elementary works, indicated by the lower prices, especially those on geology, should be read to supplement "Minerals and How they Occur."

1.—GEOLOGY.

Le Conte	"Compend of Geology"	$1.20
"	"Elements of Geology"	4.00
Dana	"Geological Story"	1.15
"	"Revised Text-book of Geology"	1.40
"	"Manual of Geology"	5.00
Shaler	"First Book of Geology"	.70
Chamberlain & Salisbury	"Geology," Vol. I.	4.00
Scott	"An Introduction to Geology"	1.90
Tarr	"Elementary Geology"	1.40
Heilprin	"The Earth and Its Story"	1.00
Winchell	"Geological Excursions"	1.25
Watts	"Geology for Beginners"	.75
Geikie	"Text-book of Geology," 2 vols.	10.00
Kemp	"Handbook of Rocks"	1.50
Branner & Newsom	"Syllabus of Economic Geology"	2.50
Ries	"Economic Geology of U.S."	2.50

2.—MINERALOGY.

Dana	"Minerals, and How to Study Them"	1.50
"	"Text-book of Mineralogy"	4.00
"	"System of Mineralogy"	12.50

Crosby	"Common Minerals and Rocks"	.60
"	"Tables for the Determination of Common Minerals"	1.75
Brush & Penfield	"Manual of Determinative Mineralogy and Blowpipe Analysis"	4.00
Moses & Parsons	"Mineralogy, Crystallography, and Blowpipe Analysis"	2.00

Price lists of papers and reports on the mineralogy and geology of Canada and the United States, and geological maps, are to be had by addressing the Director of the Geological Survey at Ottawa or Washington, respectively. Various provinces and states also have Geological Surveys or Departments of Mines which publish reports. Lists of these reports can be obtained from the respective Directors.

Price lists of specimens of minerals, rocks and fossils may be had from the Professor of Mineralogy, School of Mining, Kingston, Ont.

INDEX.

A

Abrasive materials, 83, 97, 167, 179; prices of, 227.
Accessory minerals, 120.
Acetic acid, 199.
Acid feldspar, 92, 120, 200.
Acid fumes, 55.
Acid igneous rocks, 118.
Acids, treatment of minerals with, 199.
Actinolite, 95.
Adamantine lustre, 46, 83.
Adit, 176.
Æolian rocks, 130.
Agate, 76, 125, 184.
Age divisions of rocks, 152, 157.
Age of rocks, 19, 117, 150.
Age of invertebrates, 151, 163; fishes, 151, 163; man, 151; reptiles, 151; amphibians, 151; mammals, 151.
Agencies, geological, 1, 23-35, 113, 117, 139.
Agglomerate, 130.
Agriculture, 167, 184; soils, 8, 9, 29, 134, 186; fertilizers, 138, 184.
Air, action of, on rocks, 30, 31.
Air, carbon dioxide in, 191.
Alabaster, 104.
Alaska, 168.
Albite, 91.
Alcohol lamp, 197.
Algæ, 140, 160, 211.
Alkali metals (*see* potassium and sodium).
Alkalies, 104, 134, 182.
Alkaline earth metals, 105, 182.
Alkaline sulphates, 191.
Alkaline waters, 179.
Alleghany range, 58.
Alloys, natural, in meteorites, 64; gold, 60; nickel steel, 69.
Alloy, soldering metal, 202.
Alteration of rocks and minerals, 10, 18, 23-35; feldspar, 92; granite, 120; sandstone, 131; limestone, 138.
Alum, 64, 184.
Alumina, 81.
Aluminium, ore of, 83, 170, 227; price of, 228.
Aluminium sulphate, 184.
Alveolites, 215.
Amalgam, 61.
Amalgamation, 61.
Amber, 59.
Amber mica, 89, 109.
Ambonychia, 223.
Amethyst, 75.
Ami, Dr. H. M., 2, 9, 25, 27, 107, 135, 137, 145, 148, 149.
Ammonia, 67.
Ammonite, 19, 163, 226.
Amorphous structure, 7, 141.

Amphibians, 157, 164, 226.
Amphibole, 52, 93, 138.
Amplexus, 216.
Amygdaloidal structure, 125, 142.
Analyses of clay, kaolinite, fire clay, 134; of limestones, 137.
Andes Mountains, 125.
Andesite, 118, 124.
Angles of crystals, 42, 94.
Angle of dip, 146, 188.
Anhydrite, 106.
Anhydrous, 105.
Animals, destructive action of, 32; formations due to, 32, 113; preservation of remains, 17, 151; geographical distribution of, in past ages, 19; fossil, 19, 20, 162, 213-226.
Animal kingdom, 164.
Animikie series of rocks, 154, 155.
Anorthite, 91.
Anorthosite, 123.
Anthracite, 57, 189.
Anticline, 117, 143, 144.
Antigonish, N.S., 27, 145.
Antimony, 60, 71, 228.
Anvil, 202.
Apatite, 53, 98, 109, 139, 184.
Apparatus, blowpipe, 199.
Aquamarine, 184.
Aqueous origin, ores of, 171.
Aqueous rocks, 21, 113, 119, 128-141, 143.
Aragonite, 86.
Archean, 152.
Archeology and geology, 166.
Arenaceous rocks, 131.
Argentiferous, 62, 168.
Argentite, 51, 72.
Argillaceous, defined, 132; limestones, 85, 132, 186, 190; sandstones, 132; odor, 101.
Arid regions, 140.
Arisaig, N.S., 27, 145.
Arizona, 63, 169.
Arkansas, 84.
Arkose, 132.
Armour plate, 69.
Arsenic, 68, 227.
Arsenic in paints, 183.
Arsenic trioxide, 68, 69, 227.
Arsenides, 55, 202, 203.
Arsenopyrite, 68.
Artesian wells, 192.
Artificial materials, 180.
Artois, France, 192.
Arthrophycus, 211.
Asaphus, 219.
Asbestos or asbestus, 95, 99, 180; price of, 227.
Ash, volcanic, 34, 130.
Ash beds, 130.
Association of minerals, 170, 174.
Athyris, 221.
Atmosphere, 31, 117.
Atmospheric agencies, 117.
Atrypa, 221.
Atom, 208.
Atomic weight, 208.
Augite, 93, 126.
Aulopora, 216.
Auriferous, defined, 60; 69, 168.
Australia, 165, 168.
Axes, crystallographic, 37
Azoic era, 156, 157.
Azurite, 52, 88.

B

Back-bones of fish, 20, 163.
Baker, Mr. M. B., 31.
Banded structure, 6, 179; vein, 179.
Barite, 53, 106, 170, 173, 200; in paint, 183; price of, 227.

Barium, 105; carbonate, 191.
Barlow, Dr. A. E., 115, 141, 144, 146, 151.
Barriefield, Ont., 116, 149.
Barytes (*see* barite).
Basal plane, 41, 89, 94.
Basalt, 118, 124, 142.
Basaltic structure, 126.
Basic igneous rocks, 118.
Basic minerals, 92.
Batholite, 142.
Bauxite, 83, 170, 184; price of, 227.
Beachville, Ont., 161.
Beachy Island, 14.
Beads of borax, 204.
Beaver, geological influence of, 32.
Bedded clay, 157; vein, 172.
Bedded structure, 6, 9, 133, 143.
Bedding, 30.
Bed or stratum, 117.
Bed-rock, 186.
Beet-root sugar, 138.
Belleville, 161.
Berg, ice, 29.
Beryl, 102, 170, 184.
Beryllium, 102.
Bessemer steel, 80.
Biotite, 53, 89.
Birch, 31.
Bird's Creek, Ont., *frontispiece.*
Bird's-eye formation, 157, 161.
Birds, fossil, 165, 226.
Bismuth, native, 60.
Bismuth, price of, 228.
Bismuth, test for, 72.
Bismuthinite, 72.
Bituminous coal, 57, 189.
Black as a color of minerals, 51.
Black jack, 70.
Black lead, 55.
Black mica, 89.
Black River formation, 157, 161.
Blast furnace, fuel for, 57.
Blende, zinc, 52, 70.
Blocks, volcanic, 33.
Blown sand, 31, 130.
Blowpipe tests, 194.
Blowpiping, books on, 230.
Blue glass, 183, 200.
Body or thorax, 218.
Bog-iron ore, 52, 80, 171.
Bog-lime, 138.
Boiler covering, 182.
Bones, as fertilizers, 186.
Books, list of, 229.
Borax bead, 204.
Borax in blow-piping, 198, 203, 204.
Borax, occurrence of, 193.
Bornite, 50, 68.
Boron, 98.
Boss, 117, 120, 142.
Botany, 1, 151.
Botryoidal structure, 36, 76.
Boulder, 2.
Boulder-clay, 9, 132, 157.
Brachiopods, 162, 221.
Brass tubing, 195.
Breccia, 13.
Brecciated structure, 13.
Brennan's Creek, Ont., 146.
Brick, 101, 133, 167, 189.
Brick clay, 9, 10, 189.
Bricks, white coating on, 191.
Brine, 74, 193.
Briquettes, peat, 57.
British Columbia, 24, 125, 168, 169, 170, 189.
Brittle minerals, 50.
Brock, Prof. R. W., 24.
Brockville, 161.

Brown coal, 57.
Brown hematite, 80.
Brown ochre, 80.
Buccinum, 224.
Buckler or head-shield, 218.
Buffalo, 161.
Building stone, 131, 137, 167, 184, 190.
Bunsen burner, 195.
Burn, minerals which, 202.
Butte, Montana, 168.
Bythotrephis, 211.

C

Cadmium, 209.
Cairngorm, 75.
Calamites, 212.
Calcareous, 18.
Calcareous rocks, 135, 136.
Calciferous formation, 157, 161, 214.
Calcite, 18, 53, 84, 135, 139.
Calcite, effervescence of, 199.
Calcium, 85, 104, 136.
Calcium carbide, 138.
Calcium carbonate, 18, 85, 135, 186.
Calcium fluoride, 74.
Calcium oxide, 18, 189.
Calcium phosphate, 108, 186.
Calcium sulphate, 104, 106, 140.
Calculation, chemical, 209.
California, oil in, 58; gold, 168.
Calymene, 220.
Cambrian system, 152, 156, 157, 159.
Candle in blowpiping, 195.
Canmore, 189.
Cape Smyth, 137.
Carats, fine, 60.
Carbon, 55.
Carbonate of soda, 198.
Carbonates, 55, 84, 198.
Carbon dioxide, 26, 85, 88, 100.
Carboniferous system, 157, 164, 187, 212.
Carborundum, 180.
Carbuncle, 97.
Carlow Township, 142.
Carmichael, Prof., *preface.*
Carnelian, 77.
Cassiterite, 52, 83, 120, 171
Cat's eye, 77.
Caudal shield, 218.
Caustic alkalies, 77.
Cavernous structure, 25.
Caverns, 25, 171.
Caves, 138.
Cavities, 25, 90.
Celestite, 153, 106.
Cement, 157, 158, 167, 190.
Cementing material of sedimentary rocks, 23, 114, 132.
Cement, Portland, price of, 227.
Cenozoic era, 157, 226.
Centronella, 221.
Cephalopods, 163, 225.
Ceraurus, 219.
Chætetes, 215.
Chalcedony, 76, 141.
Chalcocite, 51, 76.
Chalcopyrite, 50, 67, 168.
Chalk, 138, 227.
Chalybeate springs, 192.
Chandos Township, 115, 141.
Changes in earth's crust, 1, 113.
Charcoal, 198, 201.
Chazy formation, 157, 161, 221.
Cheirurus, 219.

Chemical, compound, composition, 3, 7, 208; elements, 209; equation, 210; formula, 208; manufacture, 167, 184; reagents, 198; symbol, 208; tests, 194, 199.
Chemically-formed rocks, 140.
Chemistry, 1, 210.
Chemung formation, 157, 160, 161.
Chert, 76, 141.
Chloride, 73.
Chlorides, in water, 192; test for, 206.
Chlorination, 61.
Chlorine, 73, 200.
Chlorite, 53, 100, 139.
Chrome iron ore, 51, 227.
Chromite, 51, 227.
Chromium, test for, 205.
Chrysolite, 96.
Chrysoprase, 77.
Chrysotile, 99.
Cinnabar, 72.
Citric acid, 198.
Classes of rocks, 21, 113.
Classification of minerals, 54.
Clastic rocks, 113.
Clay, 8, 9, 10, 11, 132-134, 170, 184.
Clayey-limestone, 136.
Clay, fire, 134, 227.
Clay for bricks, 9, 134, 189.
Clay ironstone, 78.
Clay-slate, 10, 149.
Clay-soil, 134, 185.
Cleavage, 3, 43, 70, 89.
Cleavage angle, 94.
Cleavage in slate, 149.
Cliff, 27.
Climacograptus, 214.
Climactichnites, 212.
Climate, indicated by fossils, 19.
Clinkers in coal, 57
Clinometer, 188.
Clinton formation, 157, 161, 211.
Closed tube, 105, 198, 206.
Cloth, asbestos, 180.
Coal beds, 133, 139, 189.
Coal fields, 58, 159, 187, 189.
Coal measures, 157, 160, 182.
Coal, mineral, 56, 97, 139, 172, 202, 227.
Coal mines, 16, 189.
Coal period, 181.
Coal seams, 187.
Coal, sulphur in, 57, 191.
Coarse-grained rocks, 115.
Coating on charcoal, 201.
Coating, white, on bricks, 191.
Cobalt, 69, 170, 228.
Cobalt, as coloring agent, 183; arsenate, 69; arsenide, 69; bloom, 69; nitrate, 105, 198; oxide, 227; solution, 198, 200; sulph-arsenide, 69; test for, 205.
Cobaltite, 69.
Cobalt, town of, 62, 168.
Coinage, 61, 69
Coins, gold, 61.
Coke, 57.
Collingwood, Ont., 161.
Color, 2, 46.
Columnaria, 216.
Columnar structure, 125, 126, 142.
Combining weight, 208.
Comox, B.C., 189.
Compact texture, 8.
Compass, 147, 188.
Composition, chemical, 3, 7, 209.
Composition of earth's crust, 1, 54.
Compounds, chemical, 1, 208.
Compound crystal, 94.
Conchoidal fracture, 43, 76, 108.

Concrete, materials of, 190.
Concretions, 10, 11, 76, 134.
Cone, volcanic, 33.
Conformable, 150.
Conglomerate, 12, 114, 132, 153.
Consolidation of rocks, 23.
Constancy of crystal angles, 42.
Contact, 117, 129, 171.
Contamination of water, 192.
Contorted rocks, 151.
Contraction of rocks, 148.
Copper, 87, 199.
Copper, glance, 51, 72.
Copper, native, 50, 63, 155, 168.
Copper, ores of, 168.
Copper, price of, 228.
Copper pyrites, 67, 170.
Copper sulphate, 88.
Copper, test for, 199, 205.
Copper wire, 200.
Coral reef, 136.
Corals, 19, 20, 136, 215.
Cordaites, 213.
Corkill, Mr. E. T., 89.
Corniferous formation, 156, 157, 161, 221.
Cornwall, 83, 170.
Corundum, 81, 104, 139, 142, 180, 183; price of, 227.
Cracks, mud, 15, 16.
Craigmont, Ont., 82.
Crater, volcanic, 33.
Cray-fish, 20.
Cretaceous period, 157, 189.
Crinoid, 20, 217.
Crow's Nest Pass, coal at, 189.
Crucible, 55, 62, 181.
Crumpling of rocks, 117.
Crushed stone, 190.
Crustacea, 218.
Crust of the earth, 1, 113.
Cryolite, 170, 227.
Crystal, defined, 7, 36.
Crystalline limestone, 21, 120, 138, 155, 181; as decorative material, 190; minerals in, 139.
Crystalline schists, 114.
Crystalline series of rocks, 152.
Crystallization, 37.
Crystallography, 36, 112.
Crystallography, books on, 230.
Crystals, classes of, 37, 112.
Crystal systems, 37, 112.
Crystal, twin, 39, 104.
Cube, 38.
Cubic foot of water, 49, 66.
Cupric oxide, 87.
Current bedding, 143.
Currents, 143.
Curvature of rocks, 144.
Cyanidation, 61.
Cyrtina, 221.
Cystiphyllum, 216.

D

Dalmanites, 220.
Decay of rocks, 186.
Decomposition of rocks, 113, 120, 131, 186.
Decorative materials, 167, 183.
Decrepitation, 74, 106, 200.
Definite chemical composition, 7.
Definitions, 1, 7.
Dehydrate, 105.
Dendritic, 36.
Denudation, 113.
Deposition of sediment, 30, 113.
Deposits, classification of ore, 171.
Depression, 34.
Description of minerals, 54-109.
Determination of minerals, table for, 50; books on, 230.

Detroit, 161.
Devonian system, 156, 157, 188, 213, 215, 216.
Diabase, 118, 126.
Diallage, 95, 123.
Diamond, 56, 77, 180, 183; drills, 180.
Diatom, 77, 139.
Diatomaceous earth (tripolite), 77, 139, 227.
Dicotyledons, 164.
Dicranograptus, 214.
Didymograptus, 214.
Dike, 115, 117, 141, 150.
Dikelocephalus, 218.
Dimorphism, 66.
Diorite, 118, 123.
Dip, 117, 145, 146, 147, 187, 188.
Dip-fault, 178.
Diplograptus, 214.
Dissolving in acids, 199.
Distillation of coal, 57, 58.
Distorted crystals, 42.
Dodecahedron, 38, 65, 97.
Dog-tooth spar, 84.
Dolerite, *see* diabase.
Dolomite, 53, 86, 139, 199.
Dolomitic, 136.
Double refraction, 86.
Downthrow of fault, 178.
Drainage, 184, 185, 191.
Drifts or levels, 175.
Drill holes for oil, 59, 192.
Drills, diamond, 180.
Ductile, 46.
Dunes, 31, 130, 157.
Dust, gold, 61.
Dyke (*see* dike).

E

Earth, crust of, 1, 113.
Earth, planet, 1.
Earthquake, 34.
Earth's history, 152.
Earth's surface, 113.
Earthy, 46, 100.
East Indies, 83.
Economic importance of the pre-Cambrian rocks, 155.
Economic notes, 167.
Eddies, 143.
Edmonton, 189.
Effervescence, 10, 85, 199.
Efflorescence on bricks, 191.
Effusive (or volcanic) rocks, 114.
Elastic, 88.
Electrical, 89, 182.
Eleolite (variety of nepheline), 103.
Elements, 1, 54.
Elements, table of, 208.
Elevation of land surface, 34.
Elginburg, Ont., 107.
Emerald, 103, 183.
Emery, 81, 180, 227.
Endoceras, 225.
Enstatite, 95.
Entombed remains, 152.
Eocene period, 157, 165.
Eohippus, 165.
Eozoic era, 156, 157.
Epidote, 101.
Epochs, geological, 156.
Epsom salt, 105.
Epsomite, 105.
Equisetaceæ, 212.
Equisetum, 212.
Equus, 166.
Eras, geological, 156.
Erosion, 150, 153.

Eruptive rocks (*see* igneous rocks), 21, 114-128.
Erythrite (cobalt bloom), 69.
Essential minerals, 5, 93.
Estevan, 189.
Evaporation, 140, 193.
Evolution (succession) of species, 164, 165.
Expansion by heat, 28, 31.
Experiments on minerals, 199, 201.
Explosions, volcanic, 33.
Extraction of gold, 61.

F

Fairy stones, 11.
False-bedding, 143.
Faults, 145, 177 ; models of, 177, 178.
Favosites, 19, 20, 215.
Feel of minerals and rocks, 45, 53, 78.
Feldspar, 3, 52, 90, 100, 139, 184, 185.
Feldspar group, 90.
Feldspar, lime, 91 ; potash, 91 ; soda, 91 ; cleavage of, 3, 92, 93 ; uses of, 93 ; hardness, 4, 92 ; composition of, 91 ; acid, 92 ; price of, 227.
Feldspathic, 130, 132.
Feldspathoid, 103.
Felsite, 124.
Ferric oxide, 132, 202.
Ferro-magnesian, 120.
Ferrous carbonate, 87.
Ferruginous deposits, 139.
Fertilizer, 105, 109, 184.
Fetid odor, 48.
Fibrous structure, 95.
Filiform, 36.
Field tests of minerals, table of, 50-53.
File, 197, 198.
Fire brick, 101.
Fireclay, 133, 134, 180, 227.
Fire opal, 78.
Fire-proof material, 99, 180-182.
Fire works, 106.
Fishes, 163, 226.
Fissure, 23, 113, 115.
Fissure vein, 172.
Fjords, 29.
Flagstone, 131.
Flame, blowpipe, 195.
Flame-coloration, 87, 197, 200.
Flexible, 5, 88, 99.
Filiform, 36.
Flint, 76, 141.
Flow structure, 129.
Fluid matter, 113, 115.
Fluid, petroleum, 58.
Fluorides, 55, 74.
Fluorine, 74.
Fluorite (fluor spar), 74, 98, 102, 170, 173, 193.
Fluor spar, price of, 227.
Fluxes, 74, 137.
Flux, blowpipe, 202.
Foliation (of schist), 22.
Folding of rocks, 115, 116.
Food of plants, 134, 184.
Foothills of Rockies, 189.
Fool's gold, 65.
Footprints, fossil, 16.
Foot-wall, 146, 172, 177.
Forceps, 197.
Forest, 31, 32.
Formations, geological, 156, 211-226.
Formula, chemical, 208.

Fossilization, 17.
Fossils, 17, 132, 136, 151, 154, 211-226.
Foundry castings, 80.
Fracture, 116.
Fragmental rocks, 21, 113, 153.
France, 192.
Frank, 189.
Frauds in mining, 174.
Freestone, 131.
Friable, 134.
Frogs, 164.
Frontenac County, 89, 109, 170.
Frost, 28.
Fucoids, 162, 211.
Fuel, 175, 191.
Fuel and flames, blowpipe, 195.
Fuels, mineral, 167, 187.
Furnace, 79, 182.
Fusibility, 47, 197, 200.
Fusion, 200, 203.
Fusion with borax and salt of phosphorus, 203.

G

Gabbro, 95, 118, 123.
Galena, 51, 70, 139, 169; argentiferous, 168.
Gangue, 173.
Garlic odor (mispickel), 48, 202.
Garnet, 52, 96, 139, 180, 184; price of, 227.
Garnetiferous mica schist, 179.
Gases, 26.
Gas from coal, 57.
Gas, natural, 186.
Gaspé, 213.
Gasteropods, 224.
Gelatinizing of silicates, 104, 199.
Gem, 83, 97, 98.
Gemstone, 183.
G. S. C. (Geological Survey of Canada), 2, 9, 24, 25, 27, 107, 115, 135, 137, 141, 144, 145, 146, 148, 149, 151; Reports of, 230.
Geological books, 229.
Geological map, 161.
Geological record, 152, 157, 159.
Geological science, 1.
Geological time scale, 152, 157.
Geology, 1.
Germany, 77, 185.
Gersdorfitte, 69.
Geyser, 77.
Glacial, 30, 117.
Glacial clays, 189.
Glacial period, 157, 162, 166, 187.
Glaciation, 30.
Glaciers, 30, 186.
Glass, 4, 50, 65, 69, 74, 167, 189.
Glass, cutting, 180.
Glass, coloring of, 183.
Glasses, colored, 203.
Glass, magnifying, 4, 197, 198.
Glass, manufacture of, 189.
Glass tubes, 198.
Glassy, 46, 115.
Glassy rocks, 118.
Glauber salt, 105.
Glauconite, 185.
Globe, the, 113.
Globular structure, 106.
Globules, 62.
Glyptocrinus, 217.
Gneiss, 6, 117, 120, 153.
Gneiss, granite, 6.
Gold, native, 50, 55, 60, 65, 168.
Gold, price of, 228.
Goniometer, 42.

Goodwin, Dr. W. L., *preface.*
Gossan, 67.
Grand River, 105.
Granite, 2, 75, 118, 150, 189.
Granite, jointing in, 149.
Granite-porphyry, 121.
Granitoid-gneiss, 153.
Graphic granite, 120.
Graphite, 51, 55, 139, 180, 183; from coal, 58, 187.
Graphite, price of, 227.
Graptolites, 213.
Gravel and sand, 8, 113, 153.
Greasy lustre, 99.
Great Lakes, 156, 162, 187, 189.
Great Salt Lake, 73.
Greece, 182.
Green as a color of minerals, 87, 95, 96, 98, 99, 100, 103, 108.
Greenland, 170.
Greensand (glauconite), 185.
Greenstone, 153.
Grenville, series of rocks, 154.
Grey as a color of minerals, 51.
Grinding, 81.
Grinding and polishing materials, 167, 179.
Grindstone, 83, 179, 227.
Grist mills, stones for, 179.
Ground mass of igneous rocks, 120
Groups of rocks, 21, 156.
Guano, 109.
Guelph formation, 157, 161.
Guelph, town of, 161.
Gypsum, 53, 104, 140, 184, 200; price of, 228.

H

Hæmatite or hematite, 50, 52, 78, 170.
Hackly structure, 43.
Hade (dip), 178.
Haileybury, Ont., 8, 13.
Haliburton district, Ont., 144.
Halite or rock salt, 50, 73, 193.
Halysites, 215.
Hamilton, city of, 161.
Hamilton formation, 157, 161.
Hanging-wall, 146, 172.
Hard heads, 128.
Hard minerals, 2, 45, 56.
Hardness of minerals, 4, 5, 43, 50, 110.
Harpes, 220.
Hastings County, Ont., 104, 142, 170.
Head shield, 218.
Hearthstone, 78, 98.
Heat-formed rocks, 113.
Heat, materials to withstand, 167, 180.
Heavy spar, 53, 106.
Helderberg formation, 157, 161.
Heliophyllum, 216.
Hematite, 3, 50, 52, 78, 169.
Hexagonal system, 37, 39, 84.
Hills, sand, 31, 130.
Hipparion, 165.
History, earth's, 152.
History, geology and archeology, 156, 165.
Homalonotus, 220.
Horizontal strata, 148.
Hornblende, 93.
Hornblende-syenite, 122.
Hornstone, 76.
Horse, ancestry of, 165.
Horse-flesh ore, 68.
Hot springs, 141.
Houghton, Mich., 168.
Hudson River formation, 157, 161, 189, 214, 215, 224.

Human period (age of man), 157.
Huronia, 225.
Huronian system, 152, 157.
Hydrated, 77.
Hydraulic cement, 85, 137, 138.
Hydraulic limestone, 85.
Hydrocarbons, 56.
Hydrochloric acid, 105, 108, 198, 199.
Hydrofluoric acid, 74.
Hydrogen, 208, 209.
Hydrous minerals, 206.
Hypersthene, 95, 123.

I

Ice, 28.
Ice age (glacial), 157.
Icebergs, 28.
Ice cap, 29.
Iceland spar, 85.
Ichthyocrinus, 217.
Idaho, lead, 169.
Igneous complex, 157.
Igneous origin, ores of, 123, 171, 173.
Igneous rocks, 21, 113; ore minerals in, 173.
Illuminating materials, 58, 167, 187.
Imitative shapes of minerals, 36, 76.
Impervious bed of rock, 192.
Impregnated wall, 172.
Inanimate, 29.
Inclination of rocks (dip), 147.
Inclined axes, crystal, 37.
Inclusions in minerals, 45.
Indian arrow heads, 76.
Indistinct cleavage, 103.
India, 90.
Induration (hardening) of clay, 10.
Infection from water, 192.
Infusorial earth, 139, 179.
Insulating material, 89.
Insoluble minerals, 200.
Interglacial clays, 189.
Interstratified, 58.
Intrusion, 141, 150, 153.
Intrusive rocks (*see* igneous).
Invertebrates, 158, 153.
Iodide, 72.
Iridescent, 57.
Iron cap, 67.
Iron, carbonate, 78; chromic, 51; deposits, 155; magnetic, 57, 79; meteoric, 64; native, 64; oxides, 78; sulph-arsenides, 68; sulphides, 64; test for, 202-3-5; price of, 228; as coloring agent, 64.
Iron ores, 78, 79, 139, 169; price of, 228.
Iron pyrites or pyrite, 50, 64, 170, 184; price of, 228.
Iron pyrites in coal, 57; oxidation of, 191.
Ironstone, 78.
Isometric crystals, 37, 65.
Isomorphous, 96.

J

Jasper, 13, 76, 170.
Jet beads, 205.
Jewelry, minerals in, 183, 184.
Jointed structure, 147.
Jointing in limestone, 147; in granite, 149.
Joints, 147, 148.
Jurassic period, 157, 164

K

Kaolin, 101, 134, 228.
Kaolinite, 92, 98, 132.
Kaolinization of feldspar, 101.
Keewatin system, 152, 157.
Kentucky, 186.
Keweenawan system, 152, 157.
Killaloe, Ont., 146.
Kingston Mills, 135.
Kingston, Ont., 107, 116, 135, 149, 161.

L

Labradorite, 91.
Laccolite, 142.
Lake Erie, 20, 105, 160.
Lake Huron, 20, 137, 155.
Lake Ontario, 20, 160.
Lake-ore (bog-ore). 80, 171.
Lake Superior, 77, 125, 154, 161.
Lake Temiskaming, 8, 13, 170.
Lamellar structure, 102.
Lamellibranchs, 223.
Lamination, 134.
Lamp for blowpipe, 195.
Lancaster Sound, 14.
Land plants, 187.
Land plaster, 105, 184.
Lathe, 83.
Laurentian system, 152, 157.
Laurentide Hills, 139, 153.
Lava, 142.
Leaching, 67.
Lead, 70, 72, 201.
Lead, price of, 228; oxide, 70; sulphide, 70; paint, 183.
Lead, ores of, 169, 174.
Leda, 224.
Lenticular form, 172.
Lepidodendron, 213.
Leptæna, 222.
Lethbridge, 189.
Levels or drifts, 175.
Life, 32, 162.
Lightning, 31.
Lignite, 57, 189.
Lime, 18, 137, 138, 184, 189.
Lime, quick, 191; air-slacked, 191; price of, 228; magnesian, 190.
Lime-soda feldspar, 91, 92, 123.
Limestone, 17, 135–139; *see* also crystalline limestone; of organic origin, 136, 139; argillaceous, 132; fetid, 48; conversion of, into dolomite, 136; solubility of, in carbonated water, 25, 138; weathering of, 138, 186; coral, 136; shell, 18, 137; distribution of, 138, 160, 161; consolidation of, 18; joints in, 83; alteration of, into marble, 138; lime made from, 85, 137; cement from, 190; hydraulic, 85; magnesian, 136, 137; uses of, 137; lithographic, 138; for glass-making, 189; soil from, 186.
Limonite, 52, 80, 139, 169, 171.
Lingula, 223.
List of books, 229.
Lithographic stone, 138, 193.
Lithological, 163.
Lithology, 113.
Lithrophycus, 211.
Localities, 112, 122, 168.
Lodes (*see* mineral veins).
London, Ont., 161.
Lower Helderberg, 157, 161.
Lower Huronian, 152.

Low, Mr. A. P., 14, 29.
Lubricant, graphite as a, 55.
Lustre of Minerals, 4, 46, 50, 52, 112.
Lutterworth Township, Ont., 144.
Lye, 186.
Lyndoch Township, Ont., 103.

M

Magnesia, 98, 190, 201.
Magnesian limestone, 136.
Magnesite, 87, 180, 228.
Magnesium, 54, 136.
Magnesium carbonate, 136.
Magnesium chloride, 73, 136.
Magnesium sulphate, 105.
Magnet, 11, 46, 198.
Magnetic iron ore (magnetite), 50, 79.
Magnetic pyrites, 50, 66.
Magnetic metals, 69, 202, 203.
Magnetic minerals, 46, 66, 79.
Magnetism of minerals, 46, 50, 51, 66, 79.
Magnetite, 12, 51, 79, 123, 169, 170.
Magnifying glass, 4, 198.
Malachite, 52, 87, 168.
Malleable minerals, 45.
Mammals, 158, 165, 226.
Mammilary, 87.
Mammoth, 165.
Man, as a geological agent, 32.
Man, in geological history, 165.
Manganese, 84.
Manganese dioxide, 200.
Manganese, test for, 205.
Manitoulin Island, 137.
Maple 31.
Marble, 21, 77. 138, 184.
Marble, polishing of, 180.
Marcasite, 50, 60.
Marine, 34, 136.
Maritime provinces, 187.
Markings on rocks, 14, 213.
Marl, 133, 136, 138, 157.
Marl, in cement, 190.
Marmora, Ont., 68.
Marsupials, 165.
Massive rocks, 6, 117.
Massive structure, 6.
Mastodon, 165.
Matches, 109.
Mattawa river, 28.
Mechanical mixture, 7.
Mechanically-formed rocks, 128.
Medicinal water, 191.
Medicine Hat, 189.
Medina formation, 157, 161, 189, 211.
Meerschaum, 100.
Megalomous, 224.
Mercury, 72; test for, 72; in amalgam, 61; price of, 228.
Mesabi range, 155.
Mesohippus, 165.
Mesozoic era, 157, 164, 187, 226.
Metallic lustre, 4, 46, 50, 65, 111.
Metalliferous minerals, 167, 171.
Metals and their ores, 167.
Metals, prices of, 227.
Metamorphic rocks, 21, 114, 120, 141, 151.
Metamorphism, 21, 22, 114.
Meteoric iron, 64.
Meteorite, 64, 96.
Methuen Township, 151.
Mica group, 53, 139, 180.
Mica, price of, 228; sheets of, 228.
Mica schist, 97, 120, 179.

Michelinea, 215.
Michigan, 63, 76, 153, 155, 168, 169.
Michipicoten, 169.
Microcosmic salt (phosphor), 198, 203.
Middle Huronian, 152.
Milky quartz, 75.
Mine, defined, 173; vertical section of, 175.
Mineral acids, 199.
Mineral coal, 56.
Mineral, defined, 1, 7.
Mineral fertilizers, 184.
Mineral industry, 174.
Mineralogy, 1, 229.
Mineral oil, 58.
Minerals, descriptions of, 54-109; physical characters of, 36; blowpipe characters of, 194-207; economic, 167-193; essential and accessory, 7, 120; origin of names of, 54; table for determination of, 50-53.
Mineral specimens, price lists of, *preface*, 230.
Mineral springs, 192.
Mineral veins, 24, 62, 172.
Mineral wool, 95, 180.
Minnesota, 76, 79, 155, 169.
Miocene period, 157, 165.
Miohippus, 165.
Mirabilite, 105.
Miscellaneous economic minerals, 167, 193.
Mispickel, 51, 68, 170, 202.
Missouri, lead in, 169; zinc in, 170.
Models of crystals, 37.
Models of faults, 177, 178.
Modiolaris, 223.
Modiolopsis, 223.
Molecule, 124, 209.
Mollusks, 20, 162, 221.
Molten, 113, 114, 171.
Molybdenite, 51, 56, 139.
Molybdenum, price of, 228.
Monoclinic crystals, 37, 39, 91, 94.
Montana, 63, 83, 168.
Monticulopora, 215.
Moraine (glacial debris), 157.
Mortar, 85, 138, 191.
Mortar and pestle, 202.
Moss agate, 77.
Mossy structure, 36.
Moulding sand, 193.
Mountain leather, 95.
Mountains, 189.
Mouth blowpipe, 194.
Murchisonia, 224.
Muriatic acid, 198.
Muscovite, 53, 89.

N

Names of rocks, 119; of minerals, 54.
Nanaimo, B. C., 189.
Native elements, 54, 55-64.
Native metals, 60-64, 155, 168.
Natural gas, 59, 187.
Natural rock cement, 137, 190.
Nautilus, 162.
Necks, volcanic, 142.
Nepheline, 103.
Nepheline syenite, 104, 122.
New Brunswick, 84.
New Caledonia, nickel in, 169.
Newfoundland, 34.
New Hampshire, 90.
New Jersey, 170.
New Liskeard, 8.
New York State, 73, 138, 154, 159, 162, 169.

Niagara Falls, 180.
Niagara formation, 157, 161, 215, 221.
Niccolite, 50, 69, 168.
Nickel, blowpipe test for, 205.
Nickel coins, 69.
Nickel deposits, 155.
Nickeliferous ores, 171.
Nickel in meteorites, 64.
Nickel mines, 67, 123, 168.
Nickel ore, 64, 67, 69, 123, 169, 170.
Nickel, price of, 228.
Nickel, uses of, 69.
Nicol, Prof. Wm., *preface*, *frontispiece.*
Nitrate of cobalt, 198.
Nitre, occurrence of, 193.
Nitric acid, 62, 67, 68, 108, 198, 199.
Nitrogen, 209.
Nodular structure, 36.
Nomenclature of minerals, 54; of rocks, 119.
Non-metallic, 88, 111.
Norite, 123.
Normal fault, 146, 177.
North America, coal, 57, 80, 187.
North Baffin Island, 29.
North Carolina, 83, 90.
Nova Scotia, 15, 27, 145, 168, 188.
Nuggets, 60, 62, 171.

O

Obsidian, 118, 124.
Occurrence of minerals, 170.
Ocean, 17, 140.
Ochre, 80.
Octahedron, 38, 42, 65.
Odor, 48, 101, 199. 202
Oil, mineral, 58.
Old Killaloe, Ont., 146.
Oligoclase, 91, 92.
Olivine, 96.
Olivine diabase, 126.
Onondaga formation, 157, 161.
Onyx, 77, 184.
Onyx-marble, 77.
Opal, 77.
Open tube, 53, 198, 206.
Ordovician system, 157.
Ore body, 172.
Ore, defined, 167.
Ore deposits, classified, 171; value of, 173.
Ores, prices of, 227-228.
Organic acids, 198.
Organic origin, 128.
Organically formed rocks, 128.
Organic matter, 186.
Organisms, 139.
Origin of names, 112.
Origin of ore deposits, 173.
Oriskany formation, 157, 161.
Ormoceras, 225.
Ornamental materials, 76, 87.
Orohippus, 165.
Orpiment, 69.
Orthis, 222.
Orthoceras (orthoceratite), 19, 163, 225.
Orthoclase, *frontispiece*, 91, 120.
Orthorhombic crystals, 37, 39, 105.
Ottawa, Ont., 2, 9, 148, 161.
Outcrop, 117, 138, 152.
Overhand stope, 176.
Owen Sound, 161.
Oxidation, 10, 140.
Oxides, 55; of iron, 183.
Oxidizing flame, 196.
Oxygen, 26, 54, 55, 88, 196.
Oxy-hydrogen flame, 182.

P

Paint materials, 55, 80, 108, 167, 183.
Paleontology, defined, 151.
Paleozoic era, 156, 157, 193, 211, 226.
Paraffin, 58, 195.
Paris green, 68.
Parting plane, 81.
Pass, Crow's Nest, 189.
Peacock ore, 68.
Pearly lustre, 92.
Peat, 57, 157.
Pebbles, 14.
Pegmatite, 120, 123.
Pencil, lead, 55.
Pennsylvania, coal, 187; oil, 58.
Pentagonal dodecahedron, 38, 65.
Pentamerus, 222.
Percentage composition, 209.
Periods, geological, 156-7-8.
Permian system, 157, 164.
Pestle and mortar, 202.
Peterborough County, Ont., 115, 141, 151.
Peterborough, town of, 161.
Petraia, 216.
Petrified, 18.
Petrography, defined, 113.
Petroleum, 58, 181, 187; price of, 228.
Petrology, defined, 118.
Phacops, 219.
Phillipsastrea, 216.
Phlogopite, 53, 89.
Physical characters of minerals, 36.
Phosphates, 55, 108, 184, 186.
Phosphate of soda, 198.
Phosphor-salt, 198.
Phosphatic rocks, 139.
Phosphorescence, 74.
Phosphorus, 80, 109.
Phyllograptus, 214.
Physics, 1.
Pictou, N.S., 188.
Pig iron, 228.
Pigments, 167, 183.
Pinching of veins, 146, 177
Pitchstone, 118, 124.
Pitting of plaster, 191.
Placers, 60, 63, 168, 171.
Plagioclase, 91.
Planet, 1.
Plants, age of rocks, 151, 158.
Plants, coal, 57, 133.
Plants, fossil, 151, 211.
Plants, geological effects of, 32, 113.
Plants, marine and land, 162, 165.
Plaster of Paris, 105.
Plaster, wall, 191.
Plastic clay, 10.
Plate glass, 68.
Plating, 69.
Platinum, 62, 168.
Platinum, price of, 228.
Platinum wire, 62, 196, 197, 204.
Platystrophia, 223.
Pleistocene or glacial period, 157
Pliocene period, 157, 166.
Pliohippus, 166.
Plumbago, 55.
Plutonic rocks, 114, 117, 120-123.
Polishing, 77, 81, 179.
Polluted water, 192.
Pondo Inlet, 29.
Poplar Creek, B.C., 24.
Porcelain, 69, 183.
Porphyritic granite, 120, 121.

Porphyritic structure, 120, 121, 129.
Porphyry, 121, 128.
Portage-Chemung formation, 157, 161, 212.
Port Arthur, Ont., 169, 170.
Portland cement, 136, 137, 138.
Portland cement, properties of, 190.
Post-Glacial period, 224.
Potash, 80, 185, 200.
Potash feldspar, 91.
Potassium, 54.
Pot-holes, 28.
Potsdam formation, 157, 161, 212.
Pottery, 69, 167, 183, 189.
Pre-Cambrian group of rocks, 152-155, 157, 226.
Pre-Carboniferous fossils, 211-226.
Precipitation, 139, 173.
Pressure, effects of, on rocks, 10, 56, 114, 149, 173.
Prices of minerals, 227.
Primary era, 157.
Prince Edward County, Ont., 31.
Prism, 41, 81, 109.
Protichnites, 212.
Protogine, 122.
Protohippus, 165.
Pumice, 118, 124, 179.
Purple copper ore, 68.
Pygidium, 218.
Pyramid, 41, 82, 109.
Pyrite, 50, 64, 66, 139; price of, 228.
Pyrites, arsenical, 51; copper, 50; iron, 50; magnetic, 50; white iron, 66.
Pyritohedron, 64, 65.
Pyrolusite, 51, 84.
Pyroxene, 52, 93, 123, 139.
Pyrrhotite, 50, 66, 168, 169, 199.

Q

Quarry, 149.
Quarrying, 148.
Quartz, 3, 24, 52, 75, 139, 184; gold, 168.
Quartz-porphyry (rhyolite), 153.
Quartzite, 21, 78, 120, 131, 154.
Quaternary formations, 157, 166.
Quebec, 89, 95, 99, 100, 127, 139, 170, 181.
Queen Charlotte island, 189.
Quick lime, 85, 182, 191.
Quick silver (mercury), 72, 228.
Quinze river, 127.

R

Radiated structure, 98.
Rain, 16.
Rain prints, 16.
Rain water, 24.
Reaction, chemical, 210.
Realgar, 69.
Recent, post-Glacial or Human period, 157, 188.
Red as a color of minerals, 50.
Red hematite, 50, 78.
Red ochre, 80.
Reducing flame, 196.
Reduction, 197.
Reduction of metals, 79, 202.
Reduction processes, 175.
Refraction, double, in calcite, 86.
Refractory materials, 167, 180.
Reefs, coral, 136.
Regular crystal system, 37, 38, 65.
Relative ages of rocks, 151.
Remains of animals and plants, 213.
Renfrew town, 161.
Renfrew County, Ont., 90, 103, 104
Reniform, 36.

Reptiles, fossil, 16, 158, 164, 226.
Resinous lustre, 46.
Reticulated structure, 36.
Reverse-fault, 146.
Review notes, 110, 207.
Rhamphorhyncus (flying reptile), 164.
Rhombic dodecahedron, 38, 79, 96, 97.
Rhombohedron, 39, 41, 84, 86.
Rhynconella, 221, 222.
Rhyolite, 118, 124.
Rideau canal, 135.
Ripple marks, 14, 15.
Rise or "raise," 176.
Rivers, 140, 187.
Road metal, 190.
Roasting on charcoal, 203.
Rock cement, 137.
Rock-crystal, 75.
Rock, definition of term, 7.
Rock-forming minerals, 54, 93.
Rockies, mountains, 189.
Rock oil, 187.
Rock phosphate, 109.
Rocks, acidic and basic, 118, 119.
Rock salt, 53, 73, 167, 193.
Rocks, alteration of, 23-34, 120.
Rocks and rock structures, 113.
Rocks, classification of, 21.
Rocks of organic origin, 139.
Rock structures, 113, 141.
Rocks, uses of, 2, 9, 131-4-7, 167.
Roofing material, 96.
Roofing slate, 10, 149, 228.
Rose quartz, 75.
Rossland, B.C., 67, 169.
Ruby, 81, 183.
Rusophycus, 211.
Russia, rocks in, 159

S

St. Lawrence River, 153, 161.
Saline, 48, 193.
Salt, common, 200.
Salt deposits, 73, 185.
Salt of phosphorus, 203.
Saltpetre, occurrence of, 193, 200.
Salt, rock, 53, 73, 140.
Sand, 8, 131, 173, 185.
Sand and clay, 8.
Sand dunes, 130, 157.
Sand hills, 31.
Sand-paper, 78, 180.
Sandstone, 7, 10, 131, 186; refractory, 182; for building, 189.
Sand, used in glass, 189.
Sanidine, 90.
Sapphire, 81, 183.
Sardonyx, 77.
Sarnia, Ont., 161.
Satin spar, 85.
Scale of hardness, 44, 110.
Scalenohedron, 39, 41, 84.
Scapolite, 102.
Scenery, dependent on jointing, 148.
Schist, 22.
Schistose structure, 22, 117.
Schistosity, 117, 172.
Schorl, 97.
Scratch on glass, 4, 45, 50.
Scythe stone, 179.
Sea level, 34.
Sea lilies, 217.
Sea, oscillation of level of, 34, 140.
Sea, salinity of, 74.
Sea water, 136.

Seam or bed of coal, 58.
Sebastopol, Ont., 102.
Secondary or Mesozoic era, 157.
Second order prism and pyramid, 39.
Sectile (capable of being cut), 46, 65.
Sections, geological, 116, 152, 153.
Sedimentary rocks, 113.
Segregated vein, 172.
Selenite, 104.
Serpentine, 53, 96, 98, 100, 139, 181.
Serpentinization, 96, 100.
Sets of blowpipe apparatus, 199.
Shaft, mine, 87, 175.
Shale, 17, 58, 114, 145, 189.
Shale, defined, 134.
Shallow water deposits, 17.
Sheet of mica, 228.
Sheet or sill, 142.
Shell limestone, 12, 14, 137.
Shell marl, 136.
Shore conditions, 17, 27.
Shore deposits, 17.
Siderite, 87, 169.
Sigillaria, 213.
Silica, 23, 118, 132.
Silica, in plants, 186.
Silica skeleton, 206.
Silica, test for, 206.
Silicates, 54, 55, 88.
Silicates, gelatinizing of, 199.
Silicified, 136.
Silicious, 139.
Silicon, 54.
Silicon dioxide, 75.
Silky lustre, 46.
Sills, 142.
Silurian system, 157, 216, 217.
Silver, 51, 61, 70, 168, 170.
Silver deposits, 62, 155.
Silver, price of, 228.
Sinter, 141.
Sintered cement, 190.
Slag-like, 115.
Slaking of lime, 85, 191.
Slate, 10, 120, 228.
Slate, cleavage in, 149.
Slaty cleavage, 149.
Slickensides, 177.
Smaltite, 51, 69, 168.
Smelting, 61, 78, 137.
Smoky quartz, 75.
Snails, 17.
Snakes, 20, 163.
Soapstone, 53, 98, 228.
Soda, in blowpiping, 198.
Soda-lime feldspar, 92, 123.
Sodalite, 103.
Sodium, 54, 200.
Sodium carbonate in blowpiping, 198.
Sodium carbonate, occurrence of, 193, 202, 205.
Sodium chloride, 73, 140.
Sodium phosphate, 198.
Soft coal, 57, 58.
Soft hematite, 155.
Soft minerals, 43.
Soil, formation of, 29, 185.
Soil, nature and varieties of, 8, 9, 134, 184, 185.
Solar system, 113.
Solidification of molten matter, 113.
Solubility in acids, 85, 87, 104, 199.
Solution by rain, 25; by underground water, 25; veins formed by, 24; of minerals in acids, 199.
Solution, ores from, 173, 179.

Solvent action of water, 138, 186.
Source of metals, 173.
South America, 77.
Spar, 52, 53, 74, 84, 90, 106.
Spathic iron, 87, 169.
Specific gravity of minerals, 48, 66, 111.
Specimens, 22, 111.
Spectacle glasses, 78.
Specular iron, 51, 78.
Sperrylite, 63.
Sphalerite, 52, 70, 139, 170, 199.
Sphene, 102.
Spheroidal weathering, 126, 127.
Spirifer, 221.
Spirigera, 221.
Splintery fracture, 43.
Springs, 192.
Stalactite, 76, 80, 85.
Stalagmite, 85.
Stamps for crushing, 61.
Star fish, 218.
Stassfurt, 185.
Steatite or soapstone, 53, 98.
Steel, 80, 200.
Steel forceps, 197.
Stenopora, 215.
Stibnite, 51, 71.
St. Lawrence river, 153, 161.
St. Marys, 161.
Stone and cement, 167, 190.
Stone, defined, 183.
Stopes, 175.
Stoves, 80, 89.
Straits Settlement, 170.
Strata, 128.
Strata, determination of dip of, 188.
Stratification, 117, 128, 143.
Stratified ore deposits, 171.
Stratified structure, 132, 133.
Stratum or bed, 117.
Streak of minerals, 47, 50-53.
Streak of sulphides and sulphates, 203.
Streams, work of, 26, 140, 187.
Stream tin, 83, 171.
Striated rocks, 29, 30.
Striations, 30, 65, 97, 177.
Strike-fault, 178.
Strike of rocks, 117, 146.
Strontium, 106.
Strophomena, 222.
Structural relations of rocks, 156.
Structure in rocks, 21, 22, 113, 141-150.
Sublimate on charcoal, 201.
Subsidence of the earth's crust, 34.
Subterranean waters, 173.
Subvitreous, 104.
Subulites, 224.
Succession of strata, 152.
Succession of types, 165.
Sudbury, Ont., 63, 67, 155, 168, 169, 171.
Sugar refining, 106.
Sulph-arsenides, 68, 69.
Sulphates, mineral, 55; as efflorescence products, 191; reduction of, by blowpipe, 203.
Sulphides, mineral, 55, 64, 202; detection of, 203.
Sulphides, copper, 71; lead, 70; mercury, 71; silver, 71; zinc, 70.
Sulphur, 80, 184.
Sulphur, native, 59, 67; uses of, 184, 193; springs, 192; tests for, 105, 202, 203; price of, 228.
Sulphur waters, 192.
Sulphuretted hydrogen, 192, 199.
Sulphuric acid, manufacture of, 60, 184; use in testing minerals, 74, 109.

Sulphurous odor, 48.
Sump, 176.
Sun cracks (mud cracks), 15, 16.
Superficial deposits, 171.
Superposition of strata, 150.
Surface deposits, 171.
Suspension, ores from, 173.
Swamp, 80.
Sydenham, Ont., 89.
Sydney, N.S., 188.
Syenite, 5, 118, 122, 142, 193.
Symbol, chemical, 208.
Synclines, 117, 143.
Syringopora, 215.
Systems, geological, 156.
Systems of crystallization, 37.

T

Table for the determination of minerals, 50-53.
Table of igneous rocks, 118.
Table of the elements, 206.
Talc, 53, 98, 139, 193.
Tarnish, 47, 62, 67.
Taste, 48.
Temiskaming, lake, 8, 13.
Temperature, 173.
Tertiary or Cenozoic, 157, 165.
Tests, chemical and blowpipe, 194-207.
Test substance, 196, 201.
Test tubes, 198.
Tetragonal crystals, 37, 39.
Tetrahedron, 38.
Texture of rocks, 118.
Thetford Mines, 99.
Thorax or body, 218.
Throw of fault, 178.
Thunder Bay, 155.
Tiger-eye, 77.
Till or boulder-clay, 9, 132.
Tile, 101.
Timber, 175.
Tin, ores of, 170.
Tin, price of, 228.
Tin stone or cassiterite, 52, 83, 98, 102, 170.
Titanic iron, 51.
Titanium, 80.
Titanite or sphene, 102.
Tobacco pipes, 100.
Toes of horse, 165.
Ton, 66.
Topaz, 98, 110.
Toronto, Ont., 160, 161.
Tourmaline, 52, 97, 102, 120, 184.
Trachyte, 118, 125.
Tracks, fossil, 16, 162.
Translucent, 47.
Transparent, 47.
Transportation facilities, 175.
Trap, 125, 128, 142, 153, 154.
Trapezohedron, 38, 96.
Trees, 31, 186, 187.
Tremolite, 95, 138.
Trenton formation, 157, 161, 166. 211, 215, 224.
Triarthrus, 220.
Triassic period, 157.
Triclinic crystals, 37, 39.
Trilobites, 19, 20, 162, 218.
Trinucleus, 218.
Tripolite, 77, 139, 179.
Troy ounce, 62.
Tufa, 130.
Tufaceous, 130.
Twin crystals, 39, 91, 104.

U

Unconformity, 117, 150, 159.
Underground water, 25, 192.
Underhand stope, 176.

Unit, 66.
United States, 58, 105.
Unmetallic lustre, 4, 52.
Unstratified ore deposits, 171.
Unctuous feel, 78.
Upper Huronian, 152.
Ural Mountains, 168.
Uses of minerals and rocks, 1, 167-193.
Utica formation, 157, 161, 214.

V

Valleys, 187.
Vancouver Island, 189.
Variegated copper ore, 68.
Vegetable origin of coal, 57.
Vegetation, 32, 164.
Vegetable remains, 139.
Vein-quartz, 23, 24.
Veins, 23, 24, 62, 107, 145.
Veins classified, 172; faulted, 172, 177.
Veins, origin of, 23, 116.
Vein stones, 173.
Vertebrates, 163, 164, 226.
Vesicular texture, 124.
Vinegar, 199.
Vitreous lustre, 46, 92.
Volatile ingredients, 56.
Volcanic fragmental rocks, 130, 153.
Volcanic rocks, 114, 117, 124.
Volcanoes, 32, 142; sulphur from, 59, 130.
Vug, 85.

W

Wales, rocks of, 159.
Wall (*see* hanging and foot).
Water, 23, 116, 167, 191.
Water-formed rocks, 113.
Water, medicinal, 192.
Water-lime (*see* hydraulic).
Water, test for, in minerals, 53, 206.
Waves, 27.
Wax used in blowpiping, 196.
Waxy lustre, 76, 99.
Weathering, 79, 134.
Weathering, spheroidal, 127.
Wells, 192.
Wells, oil, 59.
Wernerite or scapolite, 102.
Wheels, emery, 82, 180.
Whetstone, 82, 179.
White as a color of minerals. 51.
White arsenic, 68, 227.
White mica, 89.
Whitewash, 138.
Wind, 31.
Wind-deposited rocks, 130.
Windsor, Ont., 161.
Winze, 176.
Wood ashes, 186.
Wood pulp, 138.
Worm burrows, 162.

Y

Yellow as a color of minerals, 50.
Yellowstone National Park, 23, 141.

Z

Zaphrentis, 216.
Zinc, 52, 70, 71, 183.
Zinc blende, 52, 70, 170.
Zinc, ores of, 170, 173, 200, 209.
Zinc, price of, 228.
Zircon, 101, 120.
Zirconium, 101.
Zoology, 1, 151.

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